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NORTH AMERICAN SPECIES OF TARAXACUM[1]

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 272

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(WITH PLATES XXXI–XXXIII)

For many years our knowledge of the American species of *Taraxacum* has been in a very imperfect and chaotic state. The perusal of the more prominent manuals and floras issued in the United States during the past few decades shows a surprising confusion of forms and multiplicity of specific names. This confusion is easily accounted for by the fact that most of the *Taraxacum* forms tend strongly to intergrade, so much so that many botanists in the past have despaired of their specific segregation. Thus TORREY and GRAY (Fl. N. Amer. 2:494. 1843), after describing *Taraxacum dens-leonis* (=*T. vulgare*), wrote as an introduction to their four additional species: "The following species (the characters of which we copy from chiefly DE CANDOLLE, who keeps them distinct), as well as nearly all the genuine *Taraxaca*, are not improbably

[1] Including the West Indies, but not Greenland. The large number of new species recently proposed for Greenland by DAHLSTEDT have made it inadvisable to include the Greenland plants until a more abundant supply of Greenland material can be obtained for detailed study. So far, however, I have examined no plants from Greenland that were not clearly referable either to those species included in this treatment or to *Taraxacum nivale* Lange, a species close to *T. lyratum* but differing in having the achenes glabrous or nearly so. From a study of DAHLSTEDT's work (Archiv f. Botanik 4^8:1–41. 1905; *ibid.*, 5^9:1–44. 1906) and those of his determinations accessible to me, it appears that his "new species" are mostly synonymous with *Taraxacum lyratum*, *T. nivale*, and *T. ceratophorum*.

correctly viewed by FRIES, KOCH, and other excellent botanists, as mere varieties of this, the *Common Dandelion*."[2] At a later date we find that GRAY himself (Synopt. Fl. N. Amer. 1[2]:440. 1884) had come to regard all the continental North American forms as representing varieties of but one species, which he stated to be a "very polymorphous species."

In 1907 there appeared the classic monograph of *Taraxacum* by HANDEL-MAZZETTI. This author, evidently impressed with the desultory treatment which the genus usually had been accorded in previous studies, quoted the relevant words of REICHENBACH (Fl. Germ. Excurs. 270. 1830–1832), which are here translated: "A genus seriously forsaken heretofore, because of the negligence of writers. A positively tedious comparison of leaves, without the remaining points having been carefully investigated and clearly set forth, renders the amateurs fully as confused as are the botanists themselves. Moreover, the fruits especially must be observed, and these only in their mature state."

In HANDEL-MAZZETTI'S work there was given an admirable presentation of the various species of the genus. Even this valuable monograph, however, was rather inadequate for a critical opinion of the North American species, since there were a number of the more recently proposed species of which he obviously had not seen authentic specimens. In certain other cases his examination of American specimens was too limited, and I fail to find even the slightest mention of some of the species proposed by American authors previous to 1907. What seems worst of all, however, is that the many valid results of his research have been passed by almost unnoticed until the present day in this country. Taxonomic literature relating to *Taraxacum* in America is still weighted with inaccuracies that ought to be corrected.

The study presented herewith was undertaken in 1918. From the beginning the main purpose has been to correlate much of the material in American herbaria with HANDEL-MAZZETTI'S treatment, to corroborate his results where possible, to correct or improve and to augment where there was need, and then to present

[2] For reference to the works of FRIES, KOCH, and VOITH, touching this point, see DC. Prodr. 7:145 (footnote). 1838.

the conclusions for their easier accessibility to American students. The full generic description given by HANDEL-MAZZETTI is omitted, nor has it been attempted to repeat his extensive lists of synonyms in full. Only such synonyms are given as seem vital or as were misplaced or overlooked by him. For the sake of comparisons, however, his excellent specific descriptions have been followed closely; in the main, only such alterations have been made as considerations of brevity or accuracy would dictate.

Since the completion of my research there has appeared the recent article by STORK (Bull. Torr. Bot. Club **47**: 199–210. *pls. 6, 7*. 1920). It contains interesting data concerning sexuality, variation, and cytological aspects of certain American species, and cites several references that must be omitted here.

As may be noted in the following pages, I have found no occasion for proposing a single new species. In fact the literature of the genus has suffered seriously in the past from the persistent and repeated proposal of ill-advised and scantily considered specific names, many of them founded upon freakish or even immature material. Rather have I been compelled to reduce three species retained by HANDEL-MAZZETTI (*T. phymatocarpum*, *T. mexicanum*, and *T. lapponicum*) to synonomy, thus giving a total of only five species in our range.

Most of the work was prosecuted in the Herbarium of Field Museum, where I was afforded the fullest measure of freedom and courtesy through the kindness of the Curator, Dr. CHARLES F. MILLSPAUGH. The entire collections of *Taraxacum* in the United States National Herbarium, especially rich in specimens from Alaska and the Arctic regions, were loaned through the generosity of the Associate Curator, Mr. WILLIAM R. MAXON. All of the highly important materials in the Herbarium of the Canadian Geological Survey were loaned by Professor JAMES M. MACOUN, late of that Herbarium. Among these were a vast number of valuable specimens from western Canada and the Arctic regions. All of the nearly 800 specimens in the Herbarium of Boissier and the Herbarium of the Institut de Botanique, Geneva, were loaned by Dr. R. CHODAT. These, while mostly from Europe, Asia, and elsewhere than from North America, were of the greatest value in

promoting a better evaluation of the North American species. On two occasions I was permitted by Dr. JULIUS NIEUWLAND to study freely the specimens, several of them types, in the Greene Herbarium at the University of Notre Dame. To all of these botanists I here express my great indebtedness and gratitude. Others to whom also I am grateful for assistance rendered are: Dr. N. L. BRITTON, Director of the New York Botanical Garden; Dr. J. M. GREENMAN, Curator of the Herbarium, Missouri Botanical Garden; Dr. AVEN NELSON, President, University of Wyoming; Professor W. W. ROWLEE, Cornell University; Professor D. B. SWINGLE, Botanist and Bacteriologist, Montana Agricultural Experiment Station.

Abbreviations used for Herbaria: Hb. Boiss., Herb. Boissier; Hb. Can., Herb. Canadian Geological Survey; Hb. Chi., Herb. University of Chicago; Hb. Field, Herb. Field Museum of Natural History; Hb. N.Y., Herb. New York Botanical Garden; Hb. U.S., United States National Hebarium.

Clavis specierum

Achaenia matura rubescentia
- Folia plerumque gracilia, profunde laciniato-pinnatifida; involucri foliola exteriora plerumque patentia vel etiam recurvata.....5. *T. laevigatum*
- Folia crassiora, minus profunde pinnatifida vel etiam integra; involucri foliola exteriora plerumque adpressa.....3. *T. eriophorum*

Achaenia matura non (nisi interdum versus apicem in num. 1) rubescentia
- Achaenia matura nigrescentia (vel interdum versus apicem rubescentia) 1. *T. lyratum*
- Achaenia matura aliusmodi
  - Involucri foliola plerumque adpressa et corniculis instructa 2. *T. ceratophorum*
  - Involucri foliola ecorniculata vel raro corniculis minimis instructa, exteriora patentia vel reflexa.....4. *T. vulgare*

1. TARAXACUM LYRATUM (Led.) DC., Prodr. **7**:148. 1838; *Leontodon lyratus* Ledebour, Icon. Pl. Fl. Ross. ill. **5**:27. *pl. 497*. 1834; Fl. Altaica **4**:152. 1833; *T. phymatocarpum* Vahl, Fl. Danica **13** (fasc. 39):6. *pl. 2298*. 1840; Watson, U.S. Geol. Explor. 40th Parallel 207. 1871; *T. laevigatum* Gray, Proc. Acad. Phil. 1863, p. 70 (non Willd.); *T. officinale* var. *scopulorum* Gray, Synopt. Fl. N. Amer. 1^2:440. 1884; *T. Taraxacum* var. *scopulorum* Heller,

Cat. N. Amer. *pl. 8.* 1898; *T. scopulorum* Rydb., Mem. N.Y. Bot. Gard. **1**:455. 1900; *T. rupestre* Greene, Pittonia **4**:229. (Jan.) 1901; *T. alaskanum* Rydb., Bull. Torr. Bot. Club **28**:512. (Sept.) 1901; *T. hyperforeum* Dahlst., Videsk.-Selsk. Christ. Math.-Naturv. Kl. 1909: no. 8. p. 26. 1910; *T. eurylepium* Dahlst., *loc. cit.* 72; *T. fasciculatum* Nels., Bot. Gaz. **56**:71. 1913 (ex descript. et altitudine); *Leontodon rupestre* Rydb., Fl. Rocky Mts., 1035. 1917; *L. scopulorum* Rydb., *loc. cit.*—Pl. XXXI.

Herba valde variabilis, pusilla (interdum minima), 2–15 (–25) cm. alta. Radix tenuiuscula vel crassa, simplex vel multiceps, collo subsquamato vel foliorum vetustorum fragmentis persistentibus squamato, glabro vel sparse piloso vel sparse longo lanuginoso. Folia suberecta vel patentia, tenuia, glabra, lanceolata vel spathulata, 3–15 mm. lata, infra saepe longe attenuata, nunc integra, nunc denticulata vel sinuato-dentata, nunc regulariter incisa, lobis triangularibus vel lanceolatis, acutis vel obtusis, integris vel subdenticulatis, subrecurvis vel patentibus. Scapi plerumque pauci vel singuli, tenues, glabri vel iuveniles sub capitulo densiuscule villosi, florendi tempore foliis breviores vel multo longiores. Capitula minima (circum 7–12 mm. longa nec latiora) vel maiora (circum 12–18 mm. longa et paulo latiora). Involucri foliola pauca, atroviridiora vel nigricantia, ecorniculata vel corniculis parvis saepe instructa; exterioris seriei foliola adpressa vel laxe adcumbentia, interiorum angustiorum longitudinis 0.4–0.5 attingentia, infima vix breviora, omnia latius angustiusve ovata (latitudine 0.5–1.5 longiora), margine decolorato variabili vel nullo. Flores pauci vel numerosi, sulphurei vel flavi, involucro 1–4 mm. longiores. Achaenia maiuscula, ad 5 mm. longa, atra, fere nigra (versus apicem saepe subrubida), iuniora brunnea, tota rugosa, tuberculis largis, supra longioribus, crassis tenuioribusve obsita, abrupte in cuspidem crasse cylindricam, sulcatam, brevem vel brevissimam, totius fructus septimam partem aequantem vel quintam vix superantem contracta. Rostrum strictum, achaenio subaequilongum. Pappus illo paulo longior, albus.

Distribution.—Greenland, Arctic America, and northeastern Asia, southward at alpine heights along the mountains of western Canada and the western United States to Arizona.

SPECIMENS EXAMINED.—Alaska (and neighboring islands): Hall Island, July 14, 1899, *Brewer* and *Coe* 427 (Hb. Greene 30831); Point Gustavus, Glacier Bay, June 10–12, 1899, *Coville* and *Kearney* 732 (Hb. U.S. 376695); Haenke Island, Disenchantment Bay, June 22, 1899, *iidem* 1097 (Hb. U.S. 376702); St. Matthew Island, Bering Sea, July 15, 1899, *iidem* 2164 (Hb. U.S. 376718); Bennet, July 31, 1907, *Henry C. Cowles* 1005 (Hb. Field 419544); Clifton Point, Dolphin-Union Straits (lat. 69° 13′N.), in 1916, Rev. *H. Girling* (Hb. Can. 99071); Herald Isl., Arctic Ocean, in 1881, *Capt. C. L. Hooper* (Hb. U.S. 424060); Wollaston Land (lat. 69–70° N., long. 115° W.), July 1915, *D. Jenness* 415 (Hb. Can. 98711); Camden Bay (lat. 70° N., long. 145° W.), Collinson Point, July 17, 1914, *Frits Johansen* 115 (Hb. Can. no 98716 in Hb. Field 483378); Bernard Harbor (lat. 68° 47′ N., long. 114° 46′ W.), August 1914, *idem* 276 (Hb. Can. 98715); Cape Bathurst (lat. 70° 35′ N., long. 128° 6′ W.), July 1916, *idem* 508 (Hb. Can. 98713); Popof Isl., Shumagin Isls., July 14, 1899, *Trevor Kincaid* (Hb. U.S. 376796); Muir Glacier, July 8–19, 1899, *idem* (Hb. U.S. 376795, peculiar form with foliage of the *T. alaskanum* form and with achenes brown as in *T. ceratophorum*); Point Barrow (lat. 71° N.), steep side bank facing the ocean, July 23, 1898, *E. A. McIlhenny* (Hb. N.Y.; Hb. Can. 26283; type and cotype of *T. alaskanum* Rydb.); Point Barrow, in 1883, *Dr. John Murdoch* (Hb. U.S. 424062, 424063, and 424064, topotypes of *T. alaskanum* Rydb.); Kadiak Isl, vicinity of Karluk, July 5, 1903, *Cloudsley Rutter* 197 (Hb. U.S. 420615, the form matching LEDEBOUR's type illustration very closely); vicinity of Port Clarence, Teller Reindeer Station, tundra banks near beach July 20, 1901, *F. A. Walpole* 1492 (Hb. U.S. 378605), August 9, 1901, *idem* 1791 (Hb. U.S. 378905), and September 4, 1901, *idem* 1987 and 1988 (Hb. U.S. 379107 and 379108 respectively); vicinity of Port Clarence, banks along streams, flat west end of Tasuk Lagoon, August 22, 1901, *idem* 1895 (Hb. U.S. 379011); Arakamtchetchene Isl., Bering Staits, *C. Wright* in 1853–1856 (Hb. U.S. 424059).

British Columbia: West Summit of S. Kootenay Pass, mountain slopes, July 26, 1883, *Dawson* (Hb. Can. 15115); Chilliwhack River, alt. 6000 ft., rocky slopes, August 29, 1901, *J. M. Macoun* (Hb. Can. 26811); Hazelton, Skeena River, mountains, alt. 4500 ft., July 13, 1917, *idem* (Hb. Can. 98703; Hb. Field 483397); second summit west of Skagit River, July 24, 1905, *idem* (Hb. Can. 77001); Cascade Range, near head of McGillivray Creek, alt. 6500 ft., August 12, 1916, *idem* (Hb. Can. 98701; Hb. Field 483396); Mt. Queest, alt. 6000 ft., crevices of rocks, July 25, 1889, *idem* (Hb. Can. 15111; type of *T. rupestre* Greene); Kicking Horse Lake, alt. 8000 ft., alpine slopes, August 14, 1890, *idem* (Hb. Can. 11114; Hb. U.S. 219543); Kicking Horse Lake, damp open thickets, July 28, 1885, *John Macoun* (Hb. Can., 15110); Avalanche Mt., Selkirk Mts., alt. 8000 ft., August 4, 1890, *idem* (Hb. Can., *sine num.*); Revelstoke, alt. 1600 ft., July 26, 1905, *C. H. Shaw* 1008 (Hb. U.S. 621912); Tete Jaune Cache, headwaters of Fraser River, mountain summits, August 31, 1898, *W. Spreadborough* (Hb. Can. 19743).

Alberta: Below and at Ottertail Pass (Rocky Mt. Nat. Park), alt. 6900 ft., August 10, 1904, *John Macoun* (Hb. Can. 65620; Hb. Field 222849); Crow Nest Pass, mountain slopes, alt. 7000 ft., August 6, 1897, *idem* (Hb. Can. 23109); Fitzhugh Mt., Jasper Park, alpine summits, alt. 7000 ft., August 8, 1917, *J. M. Macoun* (Hb. Can. 98682, 98683 and 98684; Hb. Field 483384); Shovel Pass, Jasper Park, high slopes and summits, alt. 7000 ft., August 10, 1918, *idem* (Hb. Can. 98679; Hb. Field 483381); Shovel Pass, Jasper Park, among rocks at foot of cliff, alt. 6000 ft., August 17, 1918, *idem* (Hb. Can. 98680; Hb. Field 483382); Goat Mt., Jasper Park, above tree limit, alt. 7000 ft., July 18, 1918, *idem* (Hb. Can. 98681; Hb. Field 483383); Mt. Edith Cavell, Jasper Park, damp flat, alt. 6000 ft., *idem* (Hb. Can. 98690; Hb. Field 483389).

Montana: Old Hollowtop, near Pony, July 9, 1897, alt. 9000 ft., *Rydberg* and *Bessey* 5294 (Hb. U.S. 361402); above Stanton Lake, alt. 7000–7500 ft., August 1–7, 1894, *R. S. Williams* 1073 (Hb. Greene 48454; Hb. U.S. 288541).

Wyoming: Big Horn Mountains, alt. 10000 ft., July 17, 1890, anonymous (Hb. Greene 48456); without locality, *F. Tweedy* 745 pro parte (Hb. U.S. 41953).

Colorado: Mt. Hesperus, alt. 11000 ft., July 2, 1898, *Baker, Earle,* and *Tracy* 293 (Hb. Field 76097; Hb. Chi. 356356; Hb. U.S. 337212); Saguache (Sawatch) Range, alt. 12000 ft., August 1880, *T. S. Brandegee* (Hb. Field 204736); Uncompahgre River, mountain slopes, alt. 12000–13000 ft., August 1893, *C. A. Purpus* 719 (Hb. Chi. 357798).

Utah: La Sal Mts., alt. 3000–3300 m., July 7, 1911, *Rydberg* and *Garrett* 8720 (Hb. Can. 85360; Hb. U.S. 765075); Uintah Mts., above Bear River, alt. 12000 ft., August 1869, *Sereno Watson* 724 (Hb. U.S. 41943).

Nevada: Rocky Mountains, July 20, 1896, *Edward L. Greene* (Hb. Greene 48455).

Arizona: San Francisco Mts., August 27, 1889, *F. H. Knowlton* 142 (Hb. U.S. 41949).

LEDEBOUR founded his species upon Asiatic material with immature fruit, collected in stony places upon an alpine summit along the Tschuja River opposite the mouth of the Tschegan River. Several of the specimens from Alaska (for example, *Coville* and *Kearney* 1097, *Rutter* 197) match his description and plate, also specimens of the type collection (legit BUNGE, Hb. Boiss.) very closely. Many other Alaskan specimens fail to have the lateral laciniae of the leaves ovate, as described by LEDEBOUR, but acute instead. Here must be placed *T. alaskanum* Rydb., of which I have examined the type sheet, also the cotype in the Herbarium of the Canadian Geological Survey. Proceeding south from Alaska, forms may be found coming from the high alpine

altitudes of Colorado, Utah, etc., that in some cases look even specifically distinct. Such plants (for example, *Baker*, *Earle*, and *Tracy* 293, *Tweedy* 745 pro parte) are commonly dwarfed, 2–3.5 cm. high, and their diminutive involucres measure sometimes as low as 4–6 mm. in width at base during anthesis. It is these plants that GRAY named *T. laevigatum*, and later *T. officinale* var. *scopulorum*. A study of numerous other specimens, however, especially from Montana, Alberta, and British Columbia, reveals all possible intergradations between the two extremes of foliage and involucre. One of these forms is the *T. rupestre* Greene, of which I have studied the type and all the other material cited by GREENE.

Recently RYDBERG (*loc. cit.*) has created the name *Leontodon scopulorum* for the dwarf alpine forms of the Rocky Mountains, but, as both HANDEL-MAZZETTI and I have finally concluded, this dwarf form is entirely inseparable from *T. lyratum*. Also, for those who discard the name *Taraxacum* but persist in employing the name *Leontodon*, the name *Leontodon lyratus*, as it was originally published by LEDEBOUR, should suffice.

HANDEL-MAZZETTI had seen no mature fruit of the materials regarded by him as *T. lyratum;* but a duplicate (*Jas. M. Macoun*, Mts. at Kicking Horse Lake, British Columbia, Hb. U.S. 219543) of one of the specimens cited by himself (and seen by him at the University of Vienna) has several mature achenes, which are black. Numerous other Canadian specimens examined have likewise black or blackish achenes, but in certain cases these achenes are slightly reddish near the top. At times sheets of material are observed on which the specimens have variously few, many, or all of their leaves spatulate or lanceolate, with margins merely dentate or even subentire. Typical examples of this kind are: *Knowlton* 142, Arizona (Hb. U.S. 41949); *Macoun*, British Columbia (Hb. Can. 98701; Hb. Field 483396); *Coville* and *Kearney* 1097, Alaska (Hb. U.S. 376702); *Walpole* 1791, 1895, and 1987, Alaska (Hb. U.S. 378905, 379011 and 379107 respectively). These specimens are extremely important, for some of them match the specimens of *T. phymatocarpum* from Greenland so minutely that all attempts at separation are fruitless. HANDEL-MAZZETTI (*loc. cit. pl.* **7**) presents a distributional map in which he shows *T. lyratum* ran-

ging from southern Colorado northwestward through British Columbia, Alaska, and barely touching Asia.[3] For *T. phymatocarpum* he gives a more northern range, extending from Greenland westward through Alaska and slightly into Asia. My own study, however, leaves me entirely unable to maintain such a separation. To do so would necessitate in many instances actually taking materials on the same sheet, collected at the same time and place, and known to be even racially the same, and dividing them arbitrarily between the two "species," a manifestly absurd and indefensible procedure. In this connection it is interesting to note that, years ago, SERENO WATSON determined a specimen collected by himself in Utah (*Watson* 724, Hb. U.S. 41943) as *T. phymatocarpum* Vahl. He stated expressly on the label that his determination was "fide speciminis in Groen. a Rink lecti." Thus WATSON likewise was convinced of the identity of the Utah material with that of Greenland.[4]

T. fasciculatum Nels. was described from flowering specimens collected by *Alfred A. Griffin* (no. 111) from Wagon Wheel Gap, Blue Park, Colorado, alt. 11000 ft., July 21, 1912. NELSON has been unable to locate the type specimen for me, but the description ("few-several oblanceolate or oblong obtusish merely dentate or denticulate subsessile or short-petioled glabrous leaves 4–7 cm. long"), together with the high altitude recorded, indicates clearly that the plant was *T. lyratum* of the form that, from Greenland, has heretofore been termed *T. phymatocarpum*.

Occasionally a form of *T. lyratum* is found closely simulating the form of *T. ceratophorum* which GREENE described as *T. mutilum*, and differing clearly from "*T. mutilum*" only in having black achenes (for example, *Walpole* 1791 and 1987, Alaska, Hb. U.S. 378905 and 379107 respectively; *Dr. Murdoch*, Alaska, Hb. U.S. 424062 and 424064). Its foliage is long linear or linear-lanceolate, remotely and very sharply toothed. This form matches very closely the type illustrations of *T. hyperboreum* Dahlst., from Gjöa

[3] The type of *T. lyratum*, however, was collected in the interior of Asia!

[4] Elsewhere (U.S. Geol. Explor. Fortieth Parallel 207. 1871) WATSON said: "The present specimen, a single one only, is rather larger than those from Greenland, but is plainly the same plant."

Harbor, lat. 68° 37′ 38″ N., long. 96° 23′ 40″ W., and *T. eurylepium* Dahlst., from Herschell Island (cf. pl. XXXI fig. *c*). DAHLSTEDT had seen no achenes for either of his two proposed species, but a study of *Walpole* 1987 reveals the black achenes, as in typical *T. lyratum*. Numerous variations in foliage and involucre connect the form clearly with true *T. lyratum*, and make it impossible to draw any specific distinctions.

2. TARAXACUM CERATOPHORUM (Led.) DC. Prodr. **7**:146. 1838; *Leontodon ceratophorus* Ledebour, Icon. Pl. Fl. Ross. **1**:9. *pl. 34.* 1829; Fl. Altaica **4**:149. 1833; *T. montanum* Nutt. (non Mey. et DC.), Trans. Amer. Phil. Soc. n.s. **7**:430. 1841; WOOTON and STANDLEY, Contrib. U.S. Nat. Herb. **19**:627. 1915; *T. lividum* Heller, Bull. Torr. Bot. Club **24**:480. 1897 (exclud. synon. Waldst. et Kit.); *T. Chamissonis* Greene, Pittonia **4**:228. 1901; *T. lacerum* Greene, *loc. cit.* 230; *T. dumetorum* Greene, *loc. cit.* 230; *T. mutilum*, Greene, *loc. cit.* 239; *T. leiospermum* Rydb., Bull. Torr. Bot. Club **32**:137. 1905; *T. oblanceolatum* Nels. ex Rydb., Fl. Colorado 410. 1906 (ex synon. *T. dumetorum* Greene);[5] *T. lapponicum* Handel-Mazzetti, Monogr. Taraxacum 73. 1907 (saltem quantum ad plantas americanas, forsan non Kihlm.); *Leontodon dumetorum* Rydb., Fl. Rocky Mts. 1035. 1917; *L. leiospermum* Rydb., *loc. cit.*; *L. monticola* Rydb., *loc. cit.*—Pl. XXXII.

Herba valde polymorpha, plerumque robustior, 7–25 (–35) cm. alta. Radix crassiuscula, nigrescenti-corticata, collo haud vel vix squamato, glabro vel sparsissime lanato. Folia laxe procumbentia, adscendentia vel erecta, herbacea, viridia vel pallida, glabra vel infra sparsissime pilosa, lanceolata vel oblanceolata, 1–6 (–9) cm. lata, infra saepe longe attenuata, ad apicem acuta vel obtusa, leviter sinuato-dentata vel variis modis runcinato-incisa, raro integra vel tenuissime dissecta, lobis acutis, latius angustiusve triangularibus, integris vel dentatis, acutis, lobo terminali plerumque maiore. Scapi singuli vel numerosi, suberecti, florendi tempore foliis plus minusve aequilongi, denique elongati, iuveniles plus minusve lanato-pilosi. Capitula magna, 1.5–2.5 cm. alta et 2–5 cm. lata. Involucrum griseo-viride vel nigrescens, interdum pruinosum. Involucri foliola corniculis plus minusve

[5] AVEN NELSON 8236, distributed by NELSON as *T. oblanceolatum*, is likewise referable to *T. ceratophorum*.

atratis et apicem dilatatum saepe superantibus fere semper instructa, exteriora adpressa vel patentia, late ovata vel lanceolata, interiorum longitudinis $\frac{1}{6}$–$\frac{3}{5}$ (vel raro totum) aequantia, plerumque 5–15 mm. longa, margine decolorato interdum nullo sed saepius praesente et bene distincto. Flores numerosi, magni, foliolis 5–10 mm. longiores, flavi vel sulphurei. Achaenia 4–5 mm. longa, straminea vel brunnea vel griseo-brunnea, supra tuberculis angustis medioçris longitudinis dense obsita et saepe tota rugulosa, in cuspidem crassam vel angustam, brevem vel tertiae parti totius fructus aequantem cuneate attenuata. Rostrum tenue, achaenio paulo vel multo longius. Pappus albus, 5–8 mm. longus.

DISTRIBUTION.—Labrador and Alaska southward at higher altitudes to New Hampshire, Massachusetts, Montana, New Mexico, and California; in the entire Arctic region, the mountains of Central Asia, and even "in the Caucasus and in the Alps of Switzerland (a single locality)."

SPECIMENS EXAMINED.[6]—Labrador (Peninsula): Northern Labrador along the Ungava River, August 20, 1896, *Spreadborough* (Hb. Can. 14395); Ungava, *Lucien M. Turner* 613 (Hb. U.S. 222756).

Quebec: Banks of the Grand River, Gaspe County, June 30–July 3, 1904, *M. L. Fernald* (Hb. Field 465065; Hb. U.S. 605794); Rimouski County, July 4, 1907, *Fernald* and *Collins* 1210 (Hb. Can. 86493).

Keewatin: West Coast of Hudson Bay, lat. 56° N., sandy grounds, August, 1886, *James M. Macoun* (Hb. Can. 15112); Churchill, Hudson Bay, lat. 58° 50′ N., July 26, 1910, *idem* (Hb. Cornell Univ.; Hb. Can. 79286; Hb. Field 295238; important as matching exactly the form described by GREENE for his *T. mutilum*).

Manitoba: Birtle, vicinity of, along G.T. Pacif. R.R., June 26, 1906, *Macoun* and *Herriot* (Hb. Can. 77046); Forest, six miles east of, along G.T. Pacif. R.R., June 19, 1906, *iidem* (Hb. Can. 77047); Oak River, along G.T. Pacif. R.R., June 21, 1906, *iidem* (Hb. Can. 77048).

Mackenzie: Cape Barrow (south coast of Coronation Gulf), August 9, 1915, *Cox* and *O'Neil* 451 (Hb. Can. 98712; Hb. Field 483375); Fort Resolution, July 14, 1903, *Edward A. Preble* 210 (Hb. U.S. 421694).

[6] Many specimens are omitted for lack of space. As representing the extreme form with bracts ecorniculate (*T. lapponicum*), there may be added the following examples: Alberta: Near Old Man's River, damp grassy places, August 4, 1883, *Dawson* (Hb. Can. 15124). Wyoming: Northwestern part of state, August 9, 1893, *J. N. Rose* 679 (Hb. U.S. 41951). Utah: Tate Mine, near Marysvale, alt. 9000 ft., August 22, 1894, *Marcus E. Jones* 5853 (Hb. U.S. 233114); Gold Basin, La Sal Mountains, alt. 3000–3300 m., July 11, 1911, *Rydberg* and *Garrett* 8836 (Hb. U.S. 765101). California: Bear Valley, San Bernardino Mountains, in meadows, August, 1882, *S.B.* and *W. F. Parish* 1461 (Hb. Field 208755; Hb. U.S. 783095); Bear Valley, San Bernardino Mts., alt. 6500 ft., June 18, 1894, *S. B. Parish* 3131 (Hb. U.S. 214378).

Saskatchewan: Moose Jaw, open ground by the creek, June 20, 1896, *John Macoun* (Hb. Can. 12737); Moose Jaw, vicinity of, July 13, 1895, *idem* (Hb. Can. 11713); Prince Albert, camp thickets, June 29, 1896, *idem* (Hb. Can. 12283); Wood Mountain Post, thickets, June 11, 1895, *idem* (Hb. Can. 11712); Cypress Hills, thickets, June 24, 1894, *idem* (Hb. Can. 5087; labeled in GREENE's handwriting as being "part of type" of his *T. dumetorum*); Cypress Hills, springy places, June 2, 1884, *J. M. Macoun* (Hb. Can. 15131).

Assiniboia: Medicine Hat, June 8, 1894, *John Macoun* (Hb. U.S. 232067).

Montana: Bridger Mountains, alt. 7000 ft., June 14, 1897, *Rydberg* and *Bessey* 5295 (Hb. Can. 40007; Hb. Field 81947; a form having atypic foliage, possibly a hybrid); Midvale, plains, June 17, 1903, *L. M. Umbach* 75 (Hb. Field 191120; Hb. U.S. 541438); Highwood Mts., June 19, 1888, *R. S. Williams* 434 (Hb. U.S. 288542).

Wyoming: Yellowstone National Park, July 13, 1902, *Edgar A. Mearns* 1779 (Hb. U.S. 486830); Pacific Creek, 65 miles north of Point of Rocks, June 22, 1901, *Merrill* and *Wilcox* 575 (Hb. U.S. 580684).

Colorado: Ruxton Dell, alt. 2900 m., July 17, 1903, *F. E.* and *E. S. Clements* "363.1" (Hb. U.S. 580390); Camp Creek, Larimer County, semi-meadow land, July 6, 1903, *Leslie N. Goodding* 1462 (Hb. U.S. 581396); without locality (lat. 39–41° N.), in 1862 *Hall* and *Harbour* 357 (Hb. Field 17783 314685; Hb. U.S. 41940); Tennessee Pass, Lake County, July 10, 1902, *George E. Osterhout* 2645 (Hb. N.Y.; type of *Taraxacum leiospermum* Rydb.); Gray's Peak, vicinity of, alt. 12000 ft., August 1882 and 1885, *Patterson* and *Beaty* (Hb. Field 209706); Georgetown, vicinity of, June 28–August 7, 1875, *Harry N. Patterson* (Hb. Field 208950); Cuchara River, below Laveta, alt. 2100 m., May 28, 1900, *Rydberg* and *Vreeland* 5540 (Hb. Greene 48459); South Park, July 1873, *John Wolf* 268 (Hb. U.S. 41954); Central Colorado in 1873, *idem* 669 (Hb. Field 211601).

New Mexico: Santa Fe Canyon, 9 miles east of Santa Fe, alt. 8000 ft., June 2, 1897, *A. A.* and *E. Gertrude Heller* 3642 (Hb. Greene 48457; Hb. U.S. 306394; the basis, as to material examined and not as to synonomy Waldst. and Kit., of the name *Taraxacum lividum* Heller); Pecos River National Forest, at Winsor's Ranch, alt. 8400 ft., June 29, 1908, *Paul C. Standley* 4022 (Hb. U.S. 498416); Cloudcroft, June, 1912, *Elmer Stearns* 356 (Hb. U.S. 691021); Cloudcroft, vicinity of, June 30, 1899, *E. O. Wooton* (Hb. U.S. 739580 and 739583); Cox Canyon, Sacramento Mts., August 9, 1899, *idem* (Hb. U.S. 562510, 735339, and 739582); Silver Spring Canyon, Sacramento Mts., July 6, 1899, *idem* (Hb. U.S. 739581); Winter Folly, Sacramento Mts., August 13, 1899, *idem* (Hb. U.S. 735338).

Alaska (and neighboring islands): Fort St. Michaels, Norton Sound, June 23, 1865–1866, *H. M. Bannister* (Hb. Cornell Univ.; Hb. Field 301948); St. Paul Isl., July 9, 1899, *L. J. Cole* (Hb. U.S. 376691); Kadiak, July 2, 1899, *idem* (Hb. U.S. 376690); Kukak Bay, July 1–5, 1899, *Coville* and *Kearney* 1524 and 1690 (Hb. U.S. 376708 and 376711); Hall Island, July 14, 1899, *iidem* 2028 (Hb. U.S. 376716); Unalaska, July 8, 1899, *iidem* 1721 (Hb. U.S.

376713); Attu Isl., June 26, 1873, *W. H. Dall* (Hb. U.S. 424065); Unalaska, July 11, 1892, *B. W. Everman* 69 (Hb. U.S. 376727); Dutch Harbor, Unalaska Isl., July 17, 1899, *B. E. Fernow* (Hb. Cornell Univ.); Johnson River, between Cook Inlet and the Tanana River, June 27, 1899, *E. F. Glenn* (Hb. U.S. 376755; type material of *Taraxacum mutilum* Greene); Iliamna River, Lake Iliamna region, open woods, June 29, 1902, *M. W. Gorman* 80 (Hb. U.S. 420101); Copper Center, vicinity of, in 1908, *C. W. H. Heideman* 78 (Hb. U.S. 421973); Unalaska, *A. Kellogg* 301 (Hb. U.S. 424067 and 424068); Popof Isl., Shumagin Isls., July 8–19, 1899, *Trevor Kincaid* (Hb. U.S. 376794); St. Matthew Isl., August 11, 1891, *James M. Macoun* (Hb. U.S. 249296); St. Paul Isl., August 3, 1891, *idem* (Hb. Can. 20478); St. Paul Isl., dampish banks, July 13, 1896, *idem* (Hb. Can. 20479); St. Paul Isl., grassy banks, July 1897, *idem* (Hb. Can. 20481; labeled "*Taraxacum Chamissonis*, Greene typical" in Greene's own handwriting); St. Paul Isl., June 23–August 7, 1914, *idem* (Hb. Can. 94004); Kodiak Isl., crevices of rocks, May 31, 1897, *idem* (Hb. Can. 16754); Hall Isl., crevices of rocks, August 11, 1891, *idem* (Hb. Can. 20621); Unalaska, July 4, 1896, *idem* (Hb. Can. 16755; labeled typical *T. Chamissonis* by E. L. GREENE); Valley of Alatna River, about 15 miles above its mouth, July 20, 1901, *W. C. Mendenhall* (Hb. U.S. 377350); St. Paul Isl., August 4, 1891, *C. Hart Merriam* (Hb. U.S. 424071); Kenai, June 9, 1901, *H. P. Nielsen* 11 (Hb. U.S. 378436); St. Paul's Island, July 19, 1890, *Wm. Palmer* 304 (Hb. U.S. 327969); Kodiac, July 28, 1904, *C. V. Piper* 4231 (Hb. U.S. 420683); Kenai, August 18–20, 1904, *idem* 4228 (Hb. U.S. 420680); Unga Isl., Shumagin Isls., July 12–14, 1899, *DeAlton Saunders* (Hb. U.S. 376801); Adakh Isl., July 1, 1893, *C. H. Townsend* (Hb. U.S. 219332); St. Paul Isl., August 14, 1895, *True* and *Prentiss* 82 (Hb. U.S. 231549); Tuksuk Channel, vicinity of Port Clarence, rocky banks, August 5, 1901, *F. A. Walpole* 1746 (Hb. U.S. 378852); Cape Espenberg, lat. 66° 38′ N., long. 163° 46′ W., July 28, 1894, *James T. White* (Hb. U.S. 270305); St. Lawrence Isl., August 27, 1894, *idem* (Hb. U.S. 270328).

Yukon: Canyon of the Upper Liard River, lat. 60°, June 26, 1887, *Dawson* (Hb. Can. 15119; type of *Taraxacum lacerum* Greene); Coral Creek Hill, Yukon River, June 29, 1893, *Frederick Funston* 101 (Hb. U.S. 370774); Herschell Isl., lat. 69° 35′ N., long. 139° W., August 1914, *Frits Johansen* 233 (Hb. Can. 98717; Hb. Field 483379); Five Finger Rapids, July 4, 1899, *J. B. Tarleton* 72 (Hb. U.S. 391518).

British Columbia: Mt. McLean, near Lillooet, alt. 7000 ft., July 29, 1916, *J. N. Macoun* (Hb. Can. no. 98692 in Hb. Field, 483391); Mt. McLean, alt. 6500 ft., July 29, 1916, *idem* (Hb. Can. no. 98693 in Hb. Field, 483392); Mt. McLean, alt. 6300 ft., July 29, 1916, *idem* (Hb. Can. 98694); Mt. McLean, alt. 6000 ft., July 29, 1916, *idem* (Hb. Can. 98695); Mt. McLean, along irrigation ditch, alt. 5000 ft., July 3, 1916, *idem* (Hb. Can. no. 98696 in Hb. Field, 483393); Mt. McLean, alt. 6500 ft., July 22, 1916, *idem* (Hb. Can. no. 98697 in Hb. Field, 483394); Mt. McLean, alt. 5500 ft., July 19, 1916, *idem* (Hb. Can. no. 98699 in Hb. Field, 483395); Whipsaw Creek, west of

Princeton, July 24, 1905, *idem* (Hb. Can. 77000); Yale, grassy slopes, May 17, 1889, *John Macoun* (Hb. Can. 15120); Spence's Bridge, damp grassy places, May 28, 1889, *idem* (Hb. Can. 15130); Fraser River, west of, damp grassy places, June 10, 1875, *idem* (Hb. Can. 15121); Kicking Horse Lake, Rocky Mts., July 18, 1885, *idem* (Hb. U.S. 219795).

Alberta: Jasper Park, at Shovel Pass, low ground near a brook, alt. 6000–6500 ft., August 20, 1918, *James M. Macoun* (Hb. Can. nos. 98686, 98687, and 98688 in Hb. Field, 483386, 483387, and 483388, respectively); Island Creek, north of Peace River, July 15, 1903, *idem* (Hb. Can. 61240); Bragg's Creek, foothills south of Calgary, July 16, 1897, *John Macoun* (Hb. Can. 22776); Calgary, 3 miles west of, along railroad, June 7, 1897, *idem* (Hb. Can. 22792); Banff, swamps, June 27, 1891, *idem* (Hb. Can. 15127); St. Ann, June 9, 1898, *W. Spreadborough* (Hb. Can. 19744).

Utah: Uintah Mts., above Bear River, alt. 12000 ft., August 1869, *Sereno Watson* 723 (Hb. U.S. 41937); Marysvale, alt. 6000 ft., May 21, 1894, *Marcus E. Jones* 5338 (Hb. U.S. 326832; a very unique specimen with exterior bracts of involucre greatly elongated and almost equal to the interior bracts, the flowering head over 5 cm. wide).

California: Bear Valley, San Bernardino County, alt. 6500 ft., June 3, 1901, *S. B. Parish* 4977 (Hb. U.S. 414859).

Besides the specimens cited, I have examined a number from the locality (Kamchatka; also Bering Island, Commander Islands, etc.) whence LEDEBOUR obtained his type. Most of the material from that vicinity, from the Aleutian Islands, and from Alaska proper, has the outer bracts tending to be rather short, ovate, and notably blackish when dried, with the scarious margins highly distinct. This character is not constant, however, and there are numerous variations seen. South of Alaska, nearly every specimen examined has longer, more lanceolate bracts, which tend to remain pale or dark green when dried. Even here, however, there are some marked exceptions to the rule. Thus, for example, *Standley* 4022 from New Mexico (Hb. U.S. 498416) has the dark, scarious-margined, ovate outer bracts typical of the Alaskan material.

GREEN (Pittonia **4**:228. 1901), writing upon *Taraxacum* in North America, named the Bering Sea form *T. Chamissonis*.[7]

[7] While GREENE cited no type, many of the Bering Sea specimens listed (in Hb. Can. and Hb. U.S.) had been examined by him and are labeled *T. Chamissonis* in his own handwriting. As noted, the specimen by *J. M. Macoun* from St. Paul Island (Hb. Can. 20481) had been labeled "typical" by him and may be regarded as being practically type material.

He stated that "its most constant peculiarity is that of a very dark-colored, almost blackish, involucre, of which the outer scales are very broad, strictly erect, and imbricated." Reference to LEDEBOUR'S work, however, shows that this was essentially the form which LEDEBOUR described from Kamchatka as *T. ceratophorum* ("squamis omnibus erectis; exterioribus lato-lanceolatis, nigricantibus" etc.),[8] hence *T. Chamissonis* is to be regarded as typical *T. ceratophorum*.

T. lacerum Greene and *T. mutilum* Greene are plainly mere foliage forms of *T. ceratophorum*. The type sheet of *T. lacerum* (in Hb. Can.) bears four small plants. These are not noticeably different from ordinary *T. ceratophorum* except as to the unique leaves,[9] which consist only "of a linear rachis-like body and a few pairs of divaricate or retrorse subulate-linear or falcate lobes." The bracts are highly ceratophorous. I have not been permitted to examine the type of *T. mutilum* (in Hb. Mo. Bot. Gard.), but an excellent cotype, previously cited, is in the U.S. National Herbarium.[10] This has leaves slightly less reduced than in *T. lacerum*, but bracts practically as corniculate. It is matched very closely by *J. M. Macoun's* plant from Churchill, Hudson Bay (Hb. Can. 79286), and, somewhat less closely, by *White* and *Schuchert* 110 from Baffin Land. The discontinuous distribution indicated by the four collections (*T. lacerum* from northern boundary of British Columbia, *T. mutilum* from Johnson River in Alaska, from along Hudson Bay, and from Baffin Land), suggests that either these forms represent one valid species of highly interrupted range or else they are merely foliage forms of *T.*

[8] Fl. Altaica 4:149. 1833. In his still earlier work (Icon. pl. Fl. Ross. 1:9. 1829), LEDEBOUR gave only an abridged description: "L. anthodii squamis erectis infra apicem longe corniculatis; exterioribus lato-lanceolatis; interioribus lanceolatis, foliis runcinato-sinuatis: laciniis inaequalibus; majoribus subtriangularibus. Hab. in Kamtschatka. 4 Fl. Majo, Junio." His accompanying plate (*pl. 34*) is somewhat crude and shows the outer involucre spreading above the middle and consisting of narrowly lanceolate or even linear bracts. Apparently LEDEBOUR himself had noticed this discrepancy; for in his later description in the *Flora Altaica*, not only did he retain the character "lato-lanceolatis" for the outer bracts, but he actually inserted the word "omnibus" to qualify "squamis erectis."

[9] These resemble very closely those figured by HANDEL-MAZZETTI (Monogr. Taraxacum, *pl. 5. fig. 2.* 1907) for *T. balticum*, a species unknown to me.

[10] Indeed, GREENE himself had even written "type" upon the label of this specimen, although in his description he listed Hb. Mo. Bot. Gard. as containing the type.

ceratophorum. Touching this point, a parallel study of *T. lyratum* is very illuminating. In several cases I have seen among material that was positively *T. lyratum* a freakish foliage form that looked superficially just like *T. mutilum*. In fact one of these specimens (*Walpole* 1987, Hb. U.S. 379107) appears to have deceived GREENE, for he had labeled it *T. mutilum*. Inasmuch as true *T. lyratum* is seen thus to produce a similar foliage form at times, and since true *T. ceratophorum* is known to be present wherever *T. mutilum* or *T. lacerum* has been collected, there seems to be no reason for considering either *T. mutilum* or *T. lacerum* distinct from *T. ceratophorum*. At the most they evidently can rank no higher than mere forms or varieties.[11]

Many older specimens have been determined in herbaria, some by ASA GRAY, as *T. montanum* Nutt. (non Mey. et DC.), a species cited by NUTTALL from "on the banks of the Platte, in subsaline situations toward the Rocky Mountains, and in the highest valleys of the Colorado of the West." This name was retained by WOOTON and STANDLEY (Contr. U.S. Nat. Herb. **19**:627. 1915) notwithstanding the validity of the previous name *T. montanum* (Mey.) DC. RYDBERG (Fl. Rocky Mts. 1035. 1917), however, recognizing the impropriety of retaining NUTTALL'S duplicating name, created the new and similar name (*Leontodon*) *monticola*, which thus is directly equivalent by synonomy with NUTTALL'S species. Even if NUTTALL'S species had been taxonomically worthy, however, which it was not, RYDBERG'S new name for it would be invalid, as GREENE (*loc. cit.*) had already created the name *T. dumetorum* for material which came from the same region and which did not specifically differ.[12] Obviously GREENE'S name would have

[11] It may be noted, however, that HANDEL-MAZZETTI (Monogr. Taraxacum 87. *pl. 5. fig. 2.* 1907) separates an apparently corresponding form of Europe, *T. balticum*, from the broader leaved *T. paludosum* (cf. footnote 9).

[12] WOOTON and STANDLEY, and also RYDBERG do in fact present *T. dumetorum*, which they have sought to differentiate as a separate species. I have examined all the types (in Hb. Greene) and other specimens cited for *T. dumetorum* by GREENE, and can find no differences other than those that can be proved to be field variations, or that would pass with the great majority of taxonomists as typifying merely inconstant forms. NUTTALL'S description, "caliculum biserial, short and appressed, the scales ovate or lanceolate, with broad membranaceous margins; sepals not corniculate, about twelve" shows that his plant was the form later treated by HANDEL-MAZZETTI as *T. lapponicum* Kihlm. In NUTTALL'S plant the bracts were thus not corniculate, whereas in typical *T. dumetorum* cornicula are present. These distinctions, however, do not appear to be of any value specifically.

preference. Yet even here we are confronted with difficulty, since the *T. dumetorum* type specimens (from Dale Creek, Wyoming, in Hb. Greene) are clearly a mere form or variety of true *T. ceratophorum*. Indeed, an additional "quite typical" specimen cited by GREENE (*Williams* 434) had once been listed by RYDBERG himself (Fl. Montana 484. 1900) as *T. ceratophorum*. Why he later abandoned the name (vide Rydb., Fl. Rocky Mts. 1034–1035. 1917) is not clear. As already stated, the American specimens from points south of Alaska (as also many from Alaska itself) tend to have external bracts somewhat different from those of Bering Sea (that is, typical) material. These exterior bracts vary from dark to light, from short to long, from ovate to lanceolate, from corniculate or widely dilated-bifid at apex to ecorniculate and acute, from appressed to spreading.[13] Occasionally they are as long as the inner bracts. Sometimes both sets of bracts are apically dilated, sometimes only the outer or inner set. Viewed in the light of these facts, *T. dumetorum* is seen to be synonymous with *T. ceratophorum*.

HANDEL-MAZZETTI (*loc. cit.* 73), in dealing with *T. ceratophorum*, makes a singular segregation of specimens under the separate binomial *T. lapponicum* Kihlm. The range given is essentially the same as recognized by him for *T. ceratophorum*. The chief diagnostic distinction relied upon appears to be the ecorniculate character of the bracts. It is with reluctance that I am compelled to reject his treatment.[14] The species concept and "species sense" of one who, like HANDEL-MAZZETTI, has surveyed the entire genus for all the regions of the world, are naturally and very properly entitled to high respect, but the variations in the corniculate character of the bracts are so great in North American specimens as to render illogical and really impossible any such differentiation (cf. footnote 12). It does not also appear that we even have two parallel series, connected, as stated by HANDEL-MAZZETTI, with each other by numerous intermediate

[13] In one specimen from the type locality of *T. ceratophorum* (*C. Wright*, Petropaulovski, Kamchatka, 1853–1856, Hb. U.S. 424073), the outer bracts are lanceolate and their margins are scarious only to a very slight degree.

[14] At least as to North American plants. As to the status of *T. lapponicum* Kihlm. in Europe, I have seen too few specimens to judge accurately.

forms.[15] The *lapponicum* form is much less abundant and appears to be merely an offshoot from *T. ceratophorum*. Sometimes, however, especially in the northeastern part of the continent, it passes into *T. vulgare*.[16] FERNALD and ROBINSON (Gray's *Manual*, ed. 7. 865. 1908) evidently included some of these transitional forms in their *T. officinale* var. *palustre* Blytt, from "eastern Quebec to Connecticut." At the time true *T. ceratophorum* was unknown to them from New England (cf. FERNALD, Rhodora **4**:155. 1902), but since then it has been discovered by PEASE (Rhodora **19**:111 and 221. 1917) in New Hampshire; and many years before a specimen was collected by ROBBINS.[17] The true *T. officinale* var. *palustre* (*T. paludosum* [Scop.] Schlecht.) is not cited for North America by HANDEL-MAZZETTI.[18]

T. leiospermum Rydb., from Colorado, is found to differ from the ordinary *T. ceratophorum* merely in having slender ecorniculate bracts and a slightly greenish tint to the brown, less muricate achenes. In HANDEL-MAZZETTI'S treatment *T. leiospermum* would belong, more precisely, with *T. lapponicum*. Of all the many specimens that I have studied, I have found no other specimen exactly matching RYDBERG'S type (in Hb. N.Y.) in the smoothness and color of the achenes. My failure in this respect suggests that the type was merely one of the excessively numerous forms conspicuous in this genus, which apparently often are

[15] "In der ganzen Zone der Gebirge des westlichen Nordamerika ist *T. ceratophorum* mit *T. lapponicum* durch zahlreiche Formen verbunden, die in den Merkmalen der Hüllblättchen Zwischenstellungen einnehmen," *loc. cit.* 66.

[16] HANDEL-MAZZETTI (*loc. cit.* 84) gives an exhaustive treatment of numerous forms intermediate between *T. vulgare* and *T. paludosum*, the latter being a species very close to *T. lapponicum*. He cites none for America, however.

[17] I have not seen this specimen. It was found in the herbarium at Berlin by HANDEL-MAZZETTI, and was determined by him as *T. lapponicum*.

[18] At various times some of our foremost American botanists have used the names *palustre* and *alpinum* for American specimens of *T. ceratophorum*. The real *T. paludosum* (Scop.) Schlecht and *T. alpinum* (Hoppe) Heg. and Heer, dating back originally to 1772 and 1821 respectively, are not given by HANDEL-MAZZETTI for North America. While I have been unable to examine enough European material to permit of definite conclusions, it would seem that the two species are too close together. In any case, it appears certain that if American forms of *T. ceratophorum* with ecorniculate bracts are to be segregated, they must be referred to *T. paludosum* or *T. alpinum*, rather than to the more recent *T. lapponicum*.

perpetuated here and there through parthenogenetic reproduction.[19]

Taraxacum lividum Heller (exclud. synon. Waldst. et Kit.) is seen, from the specimens cited (*A. A.* and *E. G. Heller* 3642), to be likewise a form of *T. ceratophorum*. Most of the bracts are ecorniculate, thus placing the plants, in HANDEL-MAZZETTI'S treatment (*loc. cit.* 74), with *T. lapponicum*.

3. TARAXACUM ERIOPHORUM Rydb., Fl. Montana, Mem. New York Bot. Gard. 1:454. 1900 (non Schott ex Tchihatcheff, Asie mineure 3^2:372. 1860; nomen nudum quod = *T. syriacum* Boiss., fide Handel-Mazz., Monograph. Taraxacum 162. 1907); *T. ovinum* Greene, Pittonia 4:229. 1901; *T. angustifolium* Greene, *loc. cit.*; *T. ammophilum* Nels. ex Greene, *loc. cit.* 233. *L. eriophorum* Rydb., Fl. Rocky Mts. 1035. 1917, *L. angustifolium* Rydb. *loc. cit.*; *L. ammophilum* Rydb., *loc. cit.* Pl. XXXIII.

Herba polymorpha, nunc pumila et rosulata (forma descriptionis orig.), nunc robustior, 3–8 (etiam −30) cm. alta. Radix et folia et scapi eis *T. ceratophori* non conspicue dissimiles, foliis autem saepius membranaceis et pallidis, rarius profunde pinnatifidis, iuvenilibus raro longe lanuginosis versus basim. Capitula 1.5–2.5 cm. alta et paulo latiora. Involucrum pallidum vel atroviride. Involucri foliola plerumque ecorniculata vel rarissime ad apicem dilatato-corniculata et plus minusve atrata, exteriora adpressa vel minime patentia, interiorum longitudinis 0.2–0.6 aequantia, 4–15 mm. longa, margine plus minusve distincte decolorato. Flores vivi ad anthesin non observati. Achaenia 4–5 mm. longa, rufa rufopurpureave, supra tuberculis angustis vel spinulis dense obsita, saepe acute tetragona, in cuspidem crassam vel angustam, et brevem vel quartae parti totius fructus aequantem cuneate attenuata. Rostrum tenue, achaenio paulo vel multo longius. Pappus albus, 4–8 mm. longus.

DISTRIBUTION.—Alberta to Wyoming; a form with highly corniculate bracts occurs in Alaska.

SPECIMENS EXAMINED.—Alberta: Morley, meadows, etc., June 12, 1885, *John Macoun* (Hb. Can. 15117); Laggan, June 28, 1905, *idem* (Hb. Can. 65618 and 65619); Waterton Lake, Sheep Mt., July 31, 1895, *idem* (Hb. Can. 11711, type of *T. ovinum* Greene; Hb. Greene 48435).

[19] Concerning the fixation of new colors in *Taraxacum* achene coats through the operation of parthenogenesis, cf. footnote 24.

Alaska: Vicinity of Port Clarence, gravel flats near beach, Teller Reindeer Station, September 3, 1901, *F. A. Walpole* 1980 (Hb. U.S. 379098).

British Columbia: Kicking Horse Lake, Rocky Mountains, springy places, July 20, 1885, *John Macoun* (Hb. Can. 15128; Hb. Field 227895).

Montana: Sheridan, in 1892, *Mrs. L. A. Fitch* (Hb. Mont. Agric. Exper. Sta.; type); Anaconda, mountain swales, alt. 6000 ft., May 20, 1906, *J. W. Blankinship* 723 (Hb. Can. 73794; Hb. Field 225568; Hb. U.S. 541188).

Wyoming: Dale Creek, July 1, 1896, *Edward L. Greene* (Hb. Greene 48449, 48450, and 48451; the three type sheets of *T. angustifolium* Greene); Pole Creek, June 2, 1894, *Aven Nelson* 109 (Hb. U.S. 284425); Horse Creek, June 9, 1894, *idem* 205 (Hb. Field 432099; Hb. U.S. 284424); Sand Creek, Albany Co., May 31–June 1, 1900, *idem* 6987 (Hb. Greene 48427, type of *T. ammophilum* Nelson ex Greene; Hb. U.S. 433375); Sand Creek, Albany Co., June 1, 1900, *idem* 6988 ex parte (Hb. U.S. 433376).

The specimens originally distributed by NELSON (no. 6987) as *T. ammophilum* are rather small, averaging mostly under 1 dm. in height, and are of a pallid, somewhat glaucous appearance. Their achenes, when mature, are distinctly reddish, as in *T. laevigatum*. The involucral bracts are almost entirely without dilations at the apex. Except for the achenes, the plants match perfectly some plants considered by HANDEL-MAZZETTI as *T. lapponicum* Kihlm., but regarded by myself as a form or variety of *T. ceratophorum*. They are in no way referable to the European *T. laevigatum*, as suspected by HANDEL-MAZZETTI (*loc. cit.* 110), who appears never to have seen NELSON'S specimens.

Some of the material examined is darker green, but otherwise identical. *Blankinship* 723 from Montana, consisting mostly of immature specimens, is an example of this. The Blankinship plants are particularly instructive, further, in showing the aspect of immature and dwarfed plants. Some of these (for example, Hb. Field 225568) match exactly RYDBERG'S three tiny immature type specimens of *T. eriophorum* (in Hb. Mont. Agric. Exper. Sta.).[20] RYDBERG did not describe the achenes, since there were no mature ones present.[21] The immature achenes of the Blankinship collection are brown, as in RYDBERG'S type material, but the

[20] BLANKINSHIP'S plants were collected at Anaconda, a distance of only 55 miles (90 km.) from Sheridan, whence the type of *T. eriophorum* came.

[21] The name *eriophorum* alluded to the brown hairs found on the small type plants, but this character is entirely inconstant in this species and has no real taxonomic value.

nearly mature ones (for example, Hb. U.S. 541188) are distinctly reddish. Thus RYDBERG's type plants are seen to be connected perfectly with the type material of *T. ammophilum*, and, from priority, the name *T. eriophorum* must have the preference.

The type material of *T. ovinum* Greene, from Alberta, consists of several small, more or less dwarfed and immature specimens. The achenes in the oldest head found (in Hb. Can.), while not yet very reddish, have the acutely tetrangular shape that I have observed in numerous other mature specimens of *T. eriophorum*. The involucre, although sometimes duplicated by *T. ceratophorum*, is more typical of *T. eriophorum*. and there remains no doubt that *T. ovinum* is purely synonymous with *T. eriophorum*.

T. angustifolium Greene was founded upon three specimens from Dale Creek, Wyoming. The leaves and scapes are much better developed than in *T. ovinum*, the scapes reaching a height of over 2.5 dm.; but the technical characters of the head are essentially the same. Moreover, the numerous mature achenes are definitely reddish in color. GREENE (*loc. cit.* 232) termed their color "chestnut brown," but inaccurately so, for the color is fully as reddish as in many genuine specimens of the red-achened *T. laevigatum*. The leaves are rather long, slender, and graceful, but certainly do not serve to separate the plants specifically from true *T. eriophorum*.[22]

HANDEL-MAZZETTI (*loc. cit.*) has omitted *T. eriophorum* Rydb. entirely from his monograph, and it is evident that he was entirely unfamiliar with it. The species is closely parallel with *T. ceratophorum*, from which it differs in having red achenes and in having the bracts much more often slender and without dilated tips. One might wonder whether it may be only a form of *T. ceratophorum* in which the achenes are red. Various investigators have shown that apogamy or parthenogenesis is frequent in *Taraxacum*.[23] SCHKORBATOW (Entwickelungsgeschichtliche Stud. an *Taraxacum officinale* Wigg., Bot. Institut. Charkow, p. 50. 1910) also states

[22] Almost the exact counterpart to this foliage is sometimes observed in a form of *T. ceratophorum* (for example, *Mendenhall*, Valley of Alatna River, Hb. U.S. 377350).

[23] For references to the experiments and observations of RAUNKIAER, MURBECK, JUUL, and others, see IKENO, Ber. Deutsch. Bot. Gesells. **28**:394. 1910.

that various colors of achenes may thus become fixed and hereditary.[24] Whether, however, the colors will remain fixed in the achenes of all the plants of a locally generated race upon a recurrence of normal fertilization (with attendant lapse of apogamy) is doubtful. Surely subsequent cross-pollination with specimens from the antecedent stock might be expected to occur and to result, at times, in a repetition of the former achene color. In any case, the observable tendency of the achenes of *T. eriophorum* to be more sharply tetragonal and of the bracts to be undilated at the apex in a much higher percentage of specimens, makes it seem that *T. eriophorum* is not a red-fruited variety of *T. ceratophorum*, but is rather a distinct species.

The Alaskan specimen by *Walpole* (no. 1980, Hb. U.S. 379098) has slender elongate leaves, much as in the types of *T. angustifolium*, and its achenes are bright red. The involucral bracts, however, especially the inner ones, are exceedingly corniculate, much as in the extremely corniculate forms of *T. ceratophorum*.[25]

4. TARAXACUM VULGARE (Lam.) Schrank, Primit. Fl. Salisburg. 193. 1792; *Leontodon Taraxacum* Linn., Sp. Pl. **2**:798. 1753 (diagnose incompl. fide Handel-Mazz.); Pollich, Hist. plant. Palatin. **2**:379. 1777; *L. vulgare* Lamarck, Fl. Françoise **2**:113. 1778; *T. officinale* Weber, Prim. Pl. Holst. 56. 1780; Roth, Tentam. Fl. Germ. **2**²:147. 1793; *T. Dens-leonis* Desf., Fl. Atlant. **2**:228. 1800 (fide Indicis Kew., locum cit. non vidi); *T. latilobum* DC., Prodr. **7**:146. 1838; *T. mexicanum* DC., *loc. cit.*; *T. officinale* var. *palustre* Fernald and Robinson, Gray's Man., ed. 7, p. 865. 1908 (forsan non [Smith] Blytt, Bentham, et al.); *T. paradoxum* Somes, Amer. Botanist **15**:27. 1909; *L. latilobum* Britton, Britt. and Brown Ill. Fl. N. Amer., ed. 2, **3**:315, *fig. 4063*. 1913; *T. minus*

[24] "In der Natur findet man verschiedene Farben-Schattierungen an den *Taraxacum*-Früchten, von dunkelbraun bis hellgrünlich: die ausgesprochenen Färbungen in typischen Modificationen genommen (rein hellgrün und rein dunkelbraun) werden als solche durch Vererbung fixirt." (L. SCHKORBATOW, *loc. cit.* For English summary of SCHKORBATOW'S work, see CHAMBERLAIN, BOT. GAZ. **52**:167. 1911.)

[25] To those who accept HANDEL-MAZZETTI'S differentiation of North American material between *T. ceratophorum* and *T. lapponicum*, this specimen will appear correspondingly distinct from *T. eriophorum*. I have found no such intermediate forms in *T. eriophorum*, respecting dilations of the bract tips, as are abundant in *T. ceratophorum*. Nevertheless, there seems insufficient evidence at hand to warrant proposing *Walpole's* 1980 as the type of a new species.

Lon. et var. *subscaposum* Lunell (ex synon. *L. Taraxacum* Britton, etc.), Amer. Midl. Nat. **5**:31. 1917; *L. mexicanum* Rydb., Fl. Rocky Mts. 1034. 1917.

Herba plerumque maiuscula, 5–50 cm. (rarissime "–1.20 m.") alta. Radix crassa, simplex vel multiceps, fusce corticata, collo vix squamato, large lanigero vel raro glabro. Folia nunc terrae adpressa, nunc suberecta, viridia, plerumque infra et in nervo medio sparse pilosa vel rarius glaberrima, plerumque ampla, plus minusve oblanceolata (7 mm. –15 cm. lata), acuta vel obtusa, versus basim brevius longiusve angustata, rarius large dentata tantum, plerumque autem variis modis, interdum usque ad nervum medium, runcinato-incisa, lobis latius angustiusve triangularibus vel rarius linearibus, integris vel dentato-fissis, recurvis, saepe lobulis minoribus interiectis, lobo terminali plerumque maiore. Scapi numerosi vel raro singuli, erecti vel adscendentes, crassi (2–7 mm.), florendi tempore sub capitulo saltem longe lanigeri, denique raro glabri, floriferi foliis ± aequilongi, rarius multo breviores vel multo longiores. Capitula magna (solum in speciminibus depauperatis parva), circum 2–2.5 cm. longa et aperta latitudine multo maiore. Involucri foliola numerosa, utriusque seriei ± 15–20, griseo-viridia, raro atrata, interdum leviter pruinosa, ecorniculata vel raro corniculis parvis vel rarissime maioribus instructa, linea dorsali fusca nulla. Exterioris seriei foliola interioribus vix latiora, sed paulo breviora, inter se fere aequilonga, iam in alabastris adultioribus supra basim reflexa, vel raro patula vel unum alterumve eorum vel rarissime plurima semper erecta, linearia (1.3–3 mm. lata et 12–14 mm. longa) vel rarissime latiora, margine raro indistincte decolorato. Flores numerosissimi, lutei vel raro subpallidiores, involucro circum 5–10 mm. longiores. Achaenia parva, 3–4 mm. longa, pallide griseo- vel olivaceo-brunnea, supra tuberculis mediocribus longioribusve dense obsita, in cuspidem cylindricam longiusculam et tenuem vel brevissimam et crassam, totius fructus sextam vel rarius tertiam fere partem metientem abruptissime contracta. Rostrum tenue, achaenio duplo vel plus triplo longius. Pappus albus, 6–8 mm. longus, rostro brevior.

DISTRIBUTION.—Labrador and North Carolina to Alaska, California, and Mexico, and elsewhere almost throughout the world; indigenous (fide Handel-Mazz.) in meadows of Europe and Western Asia.

SPECIMENS EXAMINED.—Labrador: Rama, August 20–24, 1897, *J. D. Sornberger* 64*x* (Hb. U.S. 411050; a form with the leaves lanceolate to spatulate and not deeply incised, some of them merely denticulate).

Newfoundland: Hermitage Bay, vicinity of Balena, June 16, 1903, *William Palmer* 1365 (Hb. U.S. 492202).

Quebec: Mt. Albert, Gaspe County, by alpine brooks or in crevices of wet hornblende schist, alt. 600–1075 m., July 20, 1906, *Fernald* and *Collins* 263 (Hb. U.S. 606098); Mt. Albert, Gaspe County, meadows and fields, also on mountains, August 19, 1882, *John Macoun* (Hb. Can. 15113); Salt Lake, Anticosti Isl., pastures and fields, August 11, 1883, *idem* (Hb. Can. 15105); Orono and vicinity, fields, September 1890, *F. L.* and *LeRoy H. Harvey* 579 (Hb. U.S. 606242); Orono, June 2, 1897, *P. L. Ricker* 233 (Hb. U.S. 414356); St. Francis River, at Boundary Lake, August 14, 1902, *W. W. Eggleston* (Hb. U.S. 492531).

Massachusetts: Middleboro, May 14, 1901, *Joseph Murdoch* (Hb. Field 471888); Middleboro, May 14, 1901, *Richard Murdoch* (Hb. Field 472180).

Rhode Island: Cumberland, railroad embankment, May 9, 1900, *E. B. Chamberlain* 68 (Hb. U.S. 491069).

New York: Chemung County, roadsides and fields, May 19, 1893, *T. F. Lucy* 14529 (Hb. Field 5306); Cold Spring Harbor, Long Island, waste places, August, 1903, *H. N. Whitford* 20 (Hb. Field 144122).

Pennsylvania: Westtown Farm, Chester County, May 26, 1905, *S. P. Hadley* 1 (Hb. U.S. 646339); Ephrata, vicinity of, May 14, 1900, *A. A. Heller* (Hb. Field 430006; Hb. U.S. 407015); Conestoga Creek, east of Lancaster, *idem*, April 28, 1900 (Hb. U.S. 407016; form with finely divided leaves); Conestoga Creek, Lancaster, May 2, 1890, *John K. Small* (Hb. Field 168088 and 168089); Harrisburg, June, 1887, *idem* (Hb. Field 168174); Conewago, vicinity of, May 14, 1891 (Hb. Field 167805 and 167810).

District of Columbia: without locality, in 1863, herb. M. S. Bebb (Hb. Field 17549).

Virginia: Louden County, August 1888, *Jesse H. Holmes* (Hb. U.S. 41946 and 41948); Chatham Hill Gap, Walker Mountain, Smyth County, alt. 3000 ft., June 13, 1892, *John K. Small* (Hb. Field 390271); White Top Mountain, Smyth County, alt. 4000–5000 ft., May 28–29, 1892 (Hb. Field 390272).

West Virginia: Pickens, June 24, 1908, *Huron H. Smith* 1364 (Hb. Field 241895).

North Carolina: Roan Mountain, September 1, 1902, *W. A. Cannon* 223 (Hb. U.S. 510188).

Ontario: Kingston, May 27, 1897, *J. Fowler* (Hb. Field 83469); Kingston, May 29, 1895, *idem* (Hb. U.S. 249777).

Ohio: Dayton, abundant and troublesome as a weed, May 25, 1904, *J. Lane Reed* (Hb. U.S. 444728 and 444729; a gigantic form escaped from cultivation, the leaves becoming, before end of fruiting period, over 4 dm. long and the scapes 7.75 dm. long); Chillicothe, in 1885, *H. T. Safford* 12 (Hb. U.S. 515462).

Michigan: Schoolcraft, uncleared ground, June 11, 1903, *A. B. Burgess* 129 (Hb. Field 141460).

Indiana: Mattsville, vicinity of, in open ground, May 10, 1892, *Guy Wilson* 19 (Hb. U.S. 228418); Mishawaka, June 1891, *E. B. Uline* (Hb. Chi. 260181).

Wisconsin: Green Bay, April, *J. H. Schuette* (Hb. Field 377994); Brown County, in yard, without date, *idem* (Hb. Field 377995).

Illinois: Evanston, dry field, July 4, 1919, *Earl E. Sherff* 3087 (Hb. Field 484462 and 484463), and in rich woods, July 4, 1919, *idem* 3088 and 3090 (Hb. Field 484464, 484465 and 484468, 484469 respectively); Urbana, open thicket, May 28, 1907, *Frank C. Gates* "1561:3" (Hb. U. S. 649050).

Minnesota: Fort Snelling, May–June, 1890, *E. A. Mearns* 161 (Hb. U.S. 649285 and 649286).

Iowa: Decatur County, pastures and waysides, common, May 28, 1896, *T. J.* and *M. F. L. Fitzpatrick* (Hb. Field 123803).

Missouri: Vulcan, railway tracks, May 8, 1908, *Huron H. Smith* 449 (Hb. Field 240920).

North Dakota: Grand Forks, vicinity of, in 1894, *C. A. Egebretson* 43 (Hb. Chi. 351987).

South Dakota: Mayo, meadows, June 20, 1914, *W. H. Over* 1828 (Hb. U.S. 582845); Rapid City, alt. 3700 ft., June 25, 1892, *Per Axel Rydberg* 846 (Hb. U.S. 211334).

Nebraska: Lincoln, May 10, 1886, *T. A. Williams* (Hb. U.S. 750371).

Kansas: Riley County, grassland, in 1896, *J. B. Norton* 748 (Hb. U.S. 353535).

Alberta: Jasper Park, Cabin Creek near Jasper, roadsides, June 15, 1918, *James M. Macoun* (Hb. Can. no. 98691 in Hb. Field, 483390).

Wyoming: Crow Creek, Albany County, moist banks, July 8, 1903, *Aven Nelson* 8905 (Hb. U.S. 581938); Yellowstone National Park, October 8, 1902, *Edgar A. Mearns* 4769 (Hb. U.S. 488386).

Colorado: Norwood Hill, San Miguel County, moist river banks, alt. 7000 ft., August 17, 1912, *Ernest P. Walker* 488 (Hb. U.S. 544606); Ouray, July 24, 1897, *C. L. Shear* 4102 (Hb. U.S. 858239).

New Mexico: Las Vegas, May 19, 1909, *T. D. A. Cockerell* (Hb. U.S. 660047); Rio Arriba County, hills south of Tierra Amarilla, alt. 2300 m., April 18–May 25, 1911, *W. W. Eggleston* 6545 (Hb. U.S. 660765); Tierra Amarilla, alt. 2280 m., April 18–May 25, 1911, *idem* 6594 (Hb. U.S. 660810); Raton, in streets, alt. 2100–2380 m., June 21–22, 1911, *Paul C. Standley* 6305 (Hb. U.S. 685335); Chama, vicinity of, along river, alt. 2380–2850 m., July 8, 1911, *idem* 6589 (Hb. U.S. 685611).

Utah: Milford, wet ground, June 4, 1902, *Leslie N. Goodding* 1039 (Hb. U.S. 485541); Provo, Wasatch Mts., June 16, 1902, *idem* 1156 (Hb. Field 215750); Big Cottonwood Canyon, below Silver Lake, June 29, 1905, *Rydberg* and *Carlton* 6455 (Hb. U.S. 508591); Wasatch Mts., abundant on plateau east of Ephraim Canyon, alt. 2900 m., August 14, 1907, *Ivar Tidestrom* 230

(Hb. U.S. 506794); Salt Lake City, alt. 5000 ft., May, 1869, *Sereno Watson* 722 (Hb. U.S. 41950).

Idaho: Pine, moist flat lands, August 16, 1910, *J. Francis Macbride* 619 (Hb. U.S. 542442); New Plymouth, "a terrible pest in lawns," July 14, 1910, *idem* 711 (Hb. Field 292597; Hb. U.S. 542478); Nez Perces County, along Hatwai Creek, April 24, 1892, *J. H. Sandberg* 42 (Hb. U.S. 243000); Hailey, common in empty lots, in 1909, *Woods* and *Tidestrom* 2762 (Hb. U.S.).

Nevada: Battle Mt., alt. 1350 m., July 23, 1913, *Albert E. Hitchcock* 626 (Hb. U.S. 765964); Jarbidge, along brook, July 12, 1912, *Nelson* and *Macbride* 2048 (Hb. U.S. 544856).

Alaska: Sitka, June 14-17, 1899, *Coville* and *Kearney* 804 (Hb. U.S. 376697); Wrangell, grassy hillside, May 6, 1915, Mr. and Mrs. *Ernest P. Walker* 617 (Hb. Field 466422); Wrangell, grassy slope, May 8, 1915, *iidem* 631 (Hb. Field 466435).

British Columbia: Oak Bay, vicinity of Sidney, Vancouver Isl., roadsides, April 22, 1913, *John Macoun* (Hb. Can. no. 98700 in Hb. Field, 483380).

Washington: Waitsburg, April 14, 1897, *Robt. M. Horner* 319 (Hb. U.S. 318829).

Oregon: Keno, alt. 4000 ft., May 9, 1898, *Elmer I. Applegate* 2015 (Hb. U.S. 361604); Umatilla National Forest, alt. 4300 ft., June 11, 1912, *C. L. Keithley* (Hb. U.S. 583213); Cottonwood Canyon, Malheur County, alt. 750 m., May 20, 1896, *John B. Leiberg* 2073 (Hb. U.S. 276280).

California: Mt. Shasta, north side of, alt. 5000–10,000 ft., June 15–30, 1897, *H. E. Brown* 442 (Hb. Field 412772); Amador County, March 23, 1896, *George Hansen* 1550 (Hb. Greene 48461).

Chihuahua: Chihuahua, vicinity of, alt. about 1300 m., June 5–10, 1908, *Edward Palmer* 353 (Hb. U.S. 573818).

Coahuila and Nuevo Leon: without locality, February–October, 1880, *idem* 761 (Hb. U.S. 41955).

San Luis Potosi: Alvarez, July 13–23, 1904, *idem* 180 (Hb. U.S. 471047).

Queretaro: Without locality, in 1910–13, *Agniel* 10535 (Hb. Field 484882).

Vera Cruz: Boca del Monte, March 13, 1894, *E. W. Nelson* 226 (Hb. U.S. 252392 *pro parte*); Las Vigas, June, 1893, *idem* 22 sub nomen *Senecio* (Hb. U.S. 252058).

Puebla: Chalchicomula, vicinity of, alt. 8000–8400 ft., March 15, 1894, *idem* 237 (Hb. U.S. 252392 *pro parte*).

Mt. Orizaba: without precise locality, July 25–26, 1901, *Rose* and *Hay* 5722 (Hb. U.S. 395506).

Mt. Popocatepetl: without precise locality, August 7–8, 1901, *iidem* 6067 (Hb. U.S. 395872).

Michoacan: Morelia, in streets, November, 1889, *Alfredo Duges* (Hb. U.S. 41956).

Mexico, civitate non cit.: *Berlandier* 849 (Hb. Boiss., cotype of *T. mexicanum DC.*).

Bermuda Isls.: Flatts, roadsides, August 16, 1913, *F. S. Collins* 314 (Hb. Field 464861); Agar's Isl., "not abundant," December 4, 1915, *idem* 430 (Hb. Field 464906).

Jamaica: Cinchona, alt. 4900 ft., in 1910, *Wm. Harris* 10926 (Hb. Field 294859).

As previously stated, *T. vulgare* tends to pass into *T. ceratophorum* in the northeastern part of North America. The *T. officinale* var. *palustre* of GRAY'S *Manual* (ed. 7, p. 865, *fig. 1015*. 1908) includes some of these transitional forms; so also does *T. latilobum* DC., collected originally in Newfoundland ("invol. squamis ecorniculatis, exter. patulo-reflexis . . . . proxime ad Dentem-leonis accedit," –DC., *loc. cit.*). *Murdoch* 1624, from Massachusetts (Hb. Field 470264) is typical of the GRAY'S *Manual* illustration, and yet is easily recognized as being true *T. vulgare*. *Fernald* and *Collins* 263 (Hb. U.S. 606098) from Quebec has the involucres fairly typical of *T. vulgare*, but in general habit it approaches *T. ceratophorum;* in fact, it was originally under the latter name. *Sornberger* 64*x* (Hb. U.S. 411050) from Labrador is still another form of *T. vulgare*. Its involucres are of the *T. vulgare* kind; but the foliage exactly matches that of *Fernald's* Grand River plant of Quebec (Hb. U.S. 605794), a plant that from involucral characters is seen however to be *T. ceratophorum*. Plants collected by *L. M. Turner* at Davie's Inlet, Labrador (Hb. U.S. 222755), have involucres clearly representing *T. vulgare*, but the foliage is very strange and is closer to that of *T. ceratophorum*, although not typical for that species. It seems entirely probable that a number of these intermediate forms are hybrids.

T. mexicanum DC. is retained as a valid species by HANDEL-MAZZETTI, who had seen at least nine specimens of BERLANDIER'S original type material, but I have seen no specimens of *Taraxacum* from Mexico that were not plainly *T. vulgare*. Even the excellent cotype specimen studied (in Hb. Boiss.) matches much of the *T. vulgare* material of the northern United States in foliage, in fruit, and in involucre. Nor does HANDEL-MAZZETTI'S description indicate any truly distinctive characters. Thus, for example, he describes the cusp of the achenes as being long in *T. mexicanum* and short or very short in *T. vulgare*, but there are numerous

specimens of genuine *T. vulgare* from various points all over North America in which the cusps are very long and slender, fully as much so as in any Mexican material studied by me. DE CANDOLLE himself was in doubt as to the validity of his species, even confessing that it was too close to *T. dens-leonis* (*T. vulgare*) and was perhaps only a variety.[26] HEMSLEY (Biol. Centr. Amer. **2**:261. 1881) regarded *T. mexicanum* as synonymous with our *T. vulgare* (*T. officinale*), and my own observations are in thorough accord with HEMSLEY'S treatment.

T. paradoxum Somes was admittedly a mere freak form of *T. vulgare*, having the stem foliate with alternate leaves, not scapose. The stems were bifurcate at the top. LUNELL'S *T. minus subscaposum* was likewise a mere leafy stemmed form ("caulis unifoliatus"). Such a form was not unknown before (cf. D. MCALPINE Bot. Atlas **1**: *pl. 25, figs. 6, 13b.* 1883).

5. TARAXACUM LAEVIGATUM (Willd.) DC., Cat. Hort. Monspel. 149. 1813; *Leontodon laevigatus* Willd., Sp. Pl. **3**:1546. 1800; *T. erythrospermum* Andrz. in Besser, Enum. Pl. Volhyn., Podol., etc., 75. 1822; *L. erythrospermum* Eichw., Naturhist. Skizze Litth., Volhyn, etc., 150. 1830; *L. erythrospermum* Britton in Britt. and Brown, Ill. Fl. N. Amer. ed. 2., **3**:316. *fig. 4064.* 1913; *T. mexicanum* Wooton and Standley, Fl. New Mex. 626. 1915 (non DC.).

Herba subgracilis, 5–30 cm. alta. Radix tenuiuscula, simplex vel pluriceps, fusce corticata, collo foliorum vetustorum fragmentis persistentibus magnus, plerumque pallide brunneis large squamato, longe lanuginoso vel rarius glabro. Folia terrae adpressa vel suberecta, glabra vel infra parce pilosula, lanceolata 0.5–4 (vel serius etiam −11) cm. lata, versus basim plerumque longe angustata, fere semper tota profunde incisa vel variis modis usque ad nervum medium crebre pinnatisecta, lobis latis angustisve, plerumque acutis, integris vel largius et tenuiter dentatis, plus minusve reflexis, interiectis saepe lobulis dentiformibus, lobo terminali lateralibus paulo maiore vel etiam interdum minore. Scapi singuli vel numerosi, subtenues, erecti vel e basi procumbente adscendentes, floriferi foliis breviores vel longiores, serius plus

[26] "Nimis *T. Denti-leonis affine et forte varietas*," DC., *loc. cit.*

minusve elongati. Capitula parva vel mediocria, circum 1–2 cm. longa et paulo latiora. Involucri foliola utriusque seriei circa 11–13, pallidius atriusve griseo-viridia, glauco-pruinosa, ecorniculata vel plerumque corniculis mediocribus vel parvis instructa. Exterioris seriei foliola adpressa, patentia vel e basi patenti recurva, interioribus latiora eorumque longitudinis tertiam vel dimidiam partem vix superantia, infima ceteris breviora, omnia late vel angustius ovata vel e basi ovata triangularia (4–8 mm. longa et 1.5–3 mm. lata), margine membranaceo plerumque distinctissimo. Flores numerosi, involucro 2–4 mm. longiores, citrini vel (in speciminibus pinguibus) *T. vulgaris* floribus paulo tantum pallidiores, extus plerumque griseo vel rubro striati. Achaenia parva, ± 3–4 mm. longa, intense rufa, rufopurpurea vel fere atropurpurea, supra tuberculis longis angustis largis obsita, saepe infra quoque rugulosa, in cuspidem anguste linearem longam, totius fructus tertiam vel quartam partem superantem abrupte contracta. Rostrum tenue, achaenio dimidio vel plus duplo longius. Pappus albus, 4–7 mm. longus.

DISTRIBUTION.—Nova Scotia and Virginia to British Columbia, Idaho, and New Mexico; apparently introduced from Europe, where native, as also (fide Handel-Mazz.) in western Asia and northwestern Africa.

SPECIMENS EXAMINED.—Nova Scotia: Yarmouth, *John Macoun*, June 3, 1910 (Hb. Can. 81358).

Massachusetts: Dorchester, May 24, 1903, *John Murdoch, Jr.*, 1304 (Hb. Field 470218); Weston, May 21, 1904, *idem* 1625 (Hb. Field 470265).

Vermont: Vergennes, dry knolls in orchard, May, 28, 1899, *Ezra Brainerd* (Hb. Greene 48444); West Rutland, Twin Mountains, May 31, 1899, *W. W. Eggleston* 1416 (Hb. U.S. 364398); Shrewsbury, May 25, 1902, *idem* 2681 (Hb. U.S. 492337).

Pennsylvania: Rohrerstown, April 21, 1891, *John K. Small* (2 sheets in Hb. Field, 169751 and 169752); vicinity of Conewago, May 14, 1891, *idem* (Hb. Field 167811).

District of Columbia: Washington, university grounds, May 2, 1899, *Edward L. Greene* (Hb. Greene 48443).

Virginia: North Four Mile Run, May 1898, *Ivar Tidestrom* (Hb. Greene 48441).

Michigan: Durand, May 15, 1913, *Edward L. Greene* (Hb. Greene 22276).

Ohio: Sandusky, July 28, 1903, *E. L. Moseley* (Hb. Field 240265).

Illinois: Chicago, in yard, May 1919, *Winnifred Baantjer* (Hb. Field 485106); Urbana, University campus, April 1, 1907, *Frank C. Gates* "1369.3"

(Hb. U.S. 648981); White Heath (Piatt Co.), ballast of railroad, May 4, 1907, *idem* 1432 (Hb. U.S. 649007); Evanston, near walk, July 4, 1910, *Earl E. Sherff* 3089 (Hb. Field 484466 and 484467).

Missouri: Vicinity of Springfield, pastures, August 28, 1911, *Paul C. Standley* 8287 (Hb. U.S. 687249).

Nebraska: Omaha and vicinity, street, August 16, 1905, *Amy C. Lawton* 65 (Hb. Field 193610).

New Mexico: Chama (Rio Arriba Co.), alt. 2380 m., May 26, 1911, *W. W. Eggleston* 6665 (Hb. U.S. 660876).

Alberta: Athabasca Landing, July 28, 1914, *A. S. Hitchcock* 12158 (Hb. U.S. 885176).

Idaho: Coeur d'Aleur, abundant in lawns at city limits, August 11, 1913, *Henry J. Rust* 396 (Hb. U.S. 870324).

Wyoming: Yellowstone National Park, June 4, 1902, *Edgar A. Mearns* 939 (Hb. U.S. 486330).

British Columbia: Beavermouth, floodplain of Columbia, alt. 2400 ft., August 18, 1905, *C. H. Shaw* 1149 (Hb. U.S. 622044).

This species should not be confused with *T. laevigatum* A. Gray (Proc. Acad. Phil. 1863:70), which was synonymous with *T. lyratum* (Led.) DC. In recent American literature it has been known as *T. erythrospermum*, but HANDEL-MAZZETTI (Monogr. Taraxacum 109. 1907) has seen WILLDENOW'S original specimen of *Leontodon laevigatum* and found that *T. erythrospermum* is purely synonymous with it. BRITTON (*loc. cit.*), familiar only with the name *Taraxacum erythrospermum*, but rejecting the generic name *Taraxacum*, has lately used the name *Leontodon erythrospermum* for this species; but this last combination (made by EICHWALD in 1830) is untenable of course, since under the appellation *Leontodon*, the name *Leontodon laevigatus* antedates it by a number of years. WOOTON and STANDLEY (*loc. cit.*) have confused this species with *T. mexicanum* DC. (*T. vulgare*). From their herbarium determinations and also from their description, "achenes red," it is seen that their plants were purely *T. laevigatum*.

Specifically, *T. laevigatum* is much the most clearly marked and sharply defined of any of our native or introduced North American species of *Taraxacum*.

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SHERFF on TARAXACUM

SHERFF on TARAXACUM

SHERFF on TARAXACUM

EXPLANATION OF PLATES XXXI–XXXIII

PLATE XXXI

Taraxacum lyrata

FIGS. *a* and *j* (×0.48). *T. alaskanum* form: *Coville* and *Kearney* 1097, Haenke Isl., Hb. U.S. 376702; figs. *b* and *f* (×0.48), foliage form typical as to LEDEBOUR'S type illustration, but plants less compound at base than figured by LEDEBOUR, *Coville* and *Kearney* 2164, St. Matthew Isl., Hb. U.S. 376718; figs. *c*, *g*, and *i* (×0.63), showing (*c*) foliage form of *T. lyratum* that corresponds to *T. mutilum* form of *T. ceratophorum* and matches type figures of *T. hyperboreum* Dahlst. and *T. eurylepium* Dahlst., (*g*) foliage form matching VAHL'S type plate of *T. phymatocarpum*, and (*i*) foliage form of *T. lyratum* more nearly approaching that of LEDEBOUR'S plate, all three from *Walpole* 1791, Alaska, Hb. U.S. 378905; fig. *d* (×0.56), from type sheet of *T. alaskanum*, McIlhenny 111, Alaska, Hb. N.Y.; fig. *e* (×0.52), topotype of *T. alaskanum*, Murdoch, Alaska, Hb. U.S. 424063; fig. *h* (×0.70), foliage form closely matching some of more erect "*T. phymatocarpum*" forms from Greenland, *Knowlton* 142, Arizona, Hb. U.S. 41949; fig. *k* (×0.79), tiny dwarf form of Rocky Mts. (*T. officinale* var. *scopulorum* Gray), *Baker*, *Earle*, and *Tracy* 293, Colorado, Hb. U.S. 76097; fig. *l* (×0.67), from type sheet of *T. rupestre*, *Macoun*, British Columbia, Hb. Can. 15111.

PLATE XXXII

Taraxacum ceratophorum

FIG. *a* (×0.47),—Type material of *T. mutilum*, *Glenn*, Alaska, Hb. U.S. 376755; fig. *b* (×0.36), from type sheet of *T. lacerum*, *Dawson*, northern British-Columbia boundary, Hb. Can. 15119; fig. *c* (×0.44), type plant of *T. leiospermum; Osterhout* 2645, Colorado, Hb. N.Y.; fig. *d* (×0.47), authentic material of *T. Chamissonis*, Cole, St. Paul Isl., Hb. U.S. 376691; fig. *e* (×0.37), from one of type sheets of *T. dumetorum*, *Greene*, Wyoming, Hb. Green 48431.

PLATE XXXIII

Taraxacum eriophorum

FIG. *a* (×0.64).—From type sheet of *T. eriophorum*, *Mrs. Fitch*, Montana, Hb. Mont. Agric. Exper. Station; fig. *b* (×0.52) from one of type sheets of *T. angustifolium*, *Greene*, Wyoming, Hb. Greene 48451; fig. *c* (×0.59), from type sheet of *T. ovinum*, *Macoun*, Alberta, Hb. Can. 11711; fig. *d* (×0.47), from type sheet of *T. ammophilum*, *Nelson*, Wyoming, Hb. Greene 48427.

VISCOSITY VALUES OF PROTOPLASM AS DETERMINED BY MICRODISSECTION[1]

WILLIAM SEIFRIZ

Introduction

The first descriptions of protoplasm, written nearly a century ago, characterize it as "a living jelly." While protoplasm is often of high viscosity, any restricted statement is likely to be misleading, for the viscosity of protoplasm may vary from a consistency slightly more than that of water to that of a firm jelly. From descriptions to be found in current literature it is rather difficult to know of just what degree of viscosity the living substance might be. The difficulty lies in the fact that there has been no careful systematic attempt to ascertain the exact degree of consistency of protoplasm from numerous types of cells and under many different physiological conditions. The following paper represents such an attempt.

Method

The method used has been that of microdissection. The instrument employed in this method is a modification of the Barber pipette holder (1). It consists essentially of two needle holders, each capable of three movements. The holders are fastened to the microscope stage, and the two needles held in them project into a glass moist chamber in which the material to be worked upon is suspended in a hanging drop of water on the under side of a cover slip which forms the roof of the chamber. The needles are of glass and possess exceedingly fine but rigid tips. The technique of the microdissection method is fully described by CHAMBERS (7), to whose article the reader is referred.

The harmful consequences which are likely to result from the practice of holding material in a thin water film, and the importance of this to microdissectionists, make it advisable to direct attention

[1] Botanical Contribution from the Johns Hopkins University, no. 66.

to the frequently damaging effect of this method by presenting some experimental data.

In working with material in a hanging drop it is often very desirable to have the water film of such thinness that the material is held firmly against the cover slip. The surface tension between water and glass thus produced is quite sufficient to hold an active protozoan such as *Euplotes* in a fixed position, or to flatten out marine ova, making them more transparent and dissection easier. If the material thus subjected to surface tension suffers no appreciable distortion, no harmful consequences may result, but eggs of seaweeds and echinoderms are sufficiently pliable to be readily distorted, so that the protoplasm is subjected to an abnormal strain which frequently causes rapid deterioration.

In order to ascertain in a general way the harm done through the flattening of marine ova by a water film, I made a series of observations on the ova of the sea-urchin *Tripneustes*. These eggs were placed in a large and much spread water droplet, which was of greater depth at its center than the diameter of an egg, while toward the periphery the water film gradually thinned to an imperceptible depth. Ova in the center of the droplet were of a normal spherical shape, while those in the peripheral film were much flattened. In half an hour the viscosity of the protoplasm of those eggs in deep water had risen only slightly, while the viscosity of those in the peripheral film had greatly increased. In an hour the spherical ova had risen in viscosity a barely perceptible amount, while the flattened ones had become a firm gel. Furthermore, the distorted eggs tolerated less dissection before showing pronounced disorganization, retained the capacity for healing a wound for a shorter time, and, in a great number of cases, their entire contents dispersed suddenly at the first touch of a needle.

While the use of the surface tension of a thin water film is of value in holding material for microdissection, therefore, the method must be used cautiously. Indeed, the greatest care possible must be taken to keep the material living and normal, and to become familiar with those criteria which assist in ascertaining the exact condition of the living substance. A full appreciation of the extreme irritability of protoplasm is a prerequisite to successful microdissection.

Terminology

Biological terms of uncertain connotation will be considered when the term is first used. I shall discuss briefly a few important words in colloid chemical nomenclature which have no fixed and precise meaning to either chemist or biologist, although they are extensively used by both. THOMAS (**26**) has recently published an account of the nomenclature employed in colloid chemistry, and has in most instances suggested the preferable term to use. I shall follow his terminology strictly, with the possible exception of the words "gel," "jelly," and "coagulum," regarding which THOMAS comes to no definite decision.

In view of the widespread and lax use of the term gel it seems advisable to use the word for the general condition of a colloidal sol when it hardens, whether the hardening be through pectization, that is, coagulation of the sol (the original sense in which gel was used by GRAHAM), or whether through setting (of a gelatine sol, for example), that is, gel includes both the stiffened jelly-like form of a sol, which will redisperse, and the hard amorphous form which will not redisperse. I shall designate gels by stiffening as jellies (which has the support of BECHHOLD **3**, p. 4), and gels by coagulation as coagula.[2] Thus do we also have the corresponding verbs gelate (proposed by TAYLOR **25**, p. 10), to form gels; set, to form jellies; and coagulate, to form coagula.[3]

The employment of three terms where two might suffice may be objectionable in some respects, but it has much to recommend it when protoplasm is the colloid being studied. When protoplasm stiffens it is impossible always to determine definitely whether the mass is a coagulum or a jelly. If the hardening is excessive an undoubted coagulum results, for the living substance is then irreversible, and can be cut up into solid chunks, while, if the

[2] THOMAS (**26**, p. 12) states that BECHHOLD restricts "gel" to the coagula of sols, and terms stiffened sols "jellies." The former statement is not supported by BECHHOLD's more recent work (**3**, p. 4) where he says: "It seems preferable to me to use the expression "gel" for the general comprehensive phenomenon, and to reserve the word "jelly" for the gelatinization of a hydrophile colloid" (that is, for the gelatinized hydrophile colloid).

[3] HARDY (**12**) employs the last two terms in the same way. "The production of an insoluble gel I shall call "coagulation," that of a soluble gel "stiffening."

increase in consistency is not too great, a firm but resilient and cohesive jelly results. Between these two conditions the exact colloidal state cannot be readily determined. The general term gel is consequently applicable.[4]

Scale of viscosity values

All sciences suffer from a confusion in nomenclature, but perhaps biology more than any other. For example, "viscosity" to the physicist is a specific and accurately measurable property of matter. All fluid substances have their mathematically determined coefficients of viscosity in physics, but to the biologist viscosity has a meaning no more definite than that the substance described has a density somewhere between that of water and of steel. This vagueness, however, is not altogether the biologist's fault.

Protoplasm cannot be collected in sufficient quantity, nor would it remain normal long enough to determine its viscosity, as the physicist would determine that of a liquid, by running it through a viscosimeter; consequently, any attempt to specify the consistency of protoplasm will be more or less influenced by personal opinion. The personal element, however, can be restricted to observations, and not be allowed also to determine the connotation of loose expressions, such as "non-viscous" (an impossible term) and "very viscid sol," which may have quite a different meaning from that conveyed to the reader.

In a previous paper (**23**) a scale of viscosity was devised so that an expression such as "decidedly viscous" would hold a definite place, and thus convey some idea of approximately how viscous a "decidedly viscous" substance is. I shall retain this

[4] I have heard from the younger colloid chemists that true gels are obtainable only from emulsoids; therefore the coagulation of a suspensoid is not a gel; that is, a gel is not a coagulum; it is a jelly. Some gels (jellies) are reversible and some not. To exclude coagulation as a word descriptive of the process of hardening of emulsions would be altogether too radical a departure in biology, where we constantly speak of the coagulation of blood, of albumin, and like emulsions. I shall, with BECHHOLD, consider as coagulations such processes as cause an irreversible change, whether from emulsions or suspensoids. It would be a great service to biologists, and undoubtedly to colloid chemists themselves, if the usage of gel, jelly, and coagulum were fixed, even though arbitrarily and but tentatively.

scale, but give in addition viscosity values to each degree of consistency. These values are directly referable to definite concentrations of a dispersion (colloidal solution) of gelatine, each concentration, as nearly as could be determined, having the same consistency as that of the protoplasm which has been given a corresponding viscosity value. The gelatine used is a commercial one and readily obtained.[5]

Examination of the gelatine dispersions was done at room temperature (18° C.) in the moist chamber of the microdissection instrument, with needles identical with those employed for the dissection of protoplasm. Table I shows the viscosity values and

TABLE I

Viscosity value*	Descriptive term	Percentage of gelatine†	Substances having an equivalent viscosity‡
1.....	Watery	0.0	Water
2.....	Very liquid	0.05	.....
3.....	Liquid	0.2	.....
4.....	Slightly viscous	0.4	.....
5.....	Rather viscous	0.5	Paraffine oil.....
6.....	Decidedly viscous	0.6	.....
7.....	Very viscous	0.7	Glycerine
8.....	Extremely viscous	0.8	Bread-dough
9.....	Gel	1.0	Vaseline
10.....	Rigid gel	2.0	Firm gelatine

*The abbreviation v.v. will be used for viscosity value.

† A 1 per cent dispersion is a mixture of 1 gm. of gelatine in 99 cc. of water.

‡ All substances were examined at room temperature, 18° C.

corresponding percentages of gelatine which have been established, and these will serve as standards for the viscosity values of protoplasm given in this paper.

Just how accurate percentages of gelatine dispersions are going to prove to be as standards of viscosity is somewhat doubtful, in view of the sensitivity of gelatine to such influences as electrolytes, length of period warmed (**25,** p. 121), etc., which greatly influence its solidification temperature. The percentages of concentration at which gelatine will set, as given in the literature, vary considerably. TAYLOR states that a 10 per cent dispersion of gelatine

[5] Bacto-gelatine, "Difco" standardized, in granular form, with a moisture content less than 4 per cent, made by the Digestive Ferments Company of Detroit, and sold by Arthur H. Thomas Company of Philadelphia.

will set at a temperature of 21° C. This value as a minimum for that temperature must certainly be erroneous. BECHHOLD speaks of a 1 per cent dispersion of gelatine as a semifluid gel (presumably at room temperature), and states that "aqueous" solutions (containing only 1 per cent of water-free gelatine) gelatinize at "ice-box temperature." I find that as low as an 0.8 per cent dispersion (depending on the kind of gelatine used) will gelatinize, that is form a soft jelly, at 18° C. In view of the fact that I have employed a standardized gelatine, it is possible that the values of viscosity given may be fairly accurately verified. I have deemed it advisable to add another column of familiar substances, however, which will help stabilize the scale, and which will also more clearly indicate the exact consistency meant by any given value.

Viscosity as a criterion of the sol and gel states

While a high consistency of an emulsion is almost conclusive evidence of the gel state and a very low consistency evidence of the sol state, yet viscosity alone is not a dependable criterion of the sol and gel conditions. When the viscosity is of an intermediate grade it is of no value as even an approximate indication of the colloidal state. It will be well, therefore, to consider to what extent we are justified in using the terms gel and sol as descriptive of the physical state of protoplasm when viscosity is the only criterion. Although we read that "gels are solid" (**19**, p. 230), and although the word gel connotes to most of us a rather firm though elastic body, it is not necessarily true that all gels are rigid. In fact, this is not the case; a gel may be quite soft. FREUNDLICH, I believe, uses as an indication of the gel state the fact that the substance will support a glass rod placed upright in it. Any criterion of the gel state based on viscosity alone at best can be only approximate. Physical structure and not viscosity determines the colloidal state. We have really no ready means of determining in all instances the actual physical structure of protoplasm, and probably, therefore, should do away with the expressions sol and gel when the degree of viscosity is the only indicator of one state or the other. Where the consistency is very high or very low, however, we can safely characterize the living emulsion

as being respectively in the gel or sol state. It is the intermediate degrees of viscosity of protoplasm of whose physical structure and therefore colloidal state we are totally ignorant. Extremely viscous protoplasm (v.v. 8) is probably a gel, but whether very viscous or decidedly viscous protoplasm is cannot be conclusively stated. This matter may not appear to be a serious one at first, but a brief consideration of the indiscriminate use of the term gel in the literature will show the misinterpretations to which such usage leads.

BAYLISS (**2**) states: "There is one fact about which there can be no doubt, that is, that protoplasm behaves as a liquid"; while MATHEWS (**19**) states that protoplasm "is a jelly-like substance or technically a gel." An older investigator (RHUMBLER **22**), during a discussion on the structure of protoplasm, says that "protoplasm cannot be a solid substance," while a recent worker (HYMAN **13**) says, the fact "that isolated pieces of protoplasm assume the spherical form is not necessarily a proof of its fluid condition," and that "protoplasm is in the gel state." Each of these statements is supported by some experimental facts, but each is true only in part. Protoplasm does not always behave as a liquid (the highly viscous, quiescent protoplasm of bread mold, for example), nor is it always a gel (as for example the very liquid endoplasm of *Euplotes*). KITE (**15**) has well expressed the exact state of affairs as follows: "Living matter occupies an intermediate position between true solids and true liquids and has many of the properties of both as well as properties peculiar to itself. It belongs to the class of colloids known as emulsoids and exists in either a gel (hydrogel) or a sol (hydrosol) state." Unfortunately, however, KITE then proceeds to use gel as descriptive of protoplasm regardless of viscosity. To be sure, viscosity is not a precise index of physical structure, but with ordinary illumination we have no other criterion by which to judge the exact colloidal state of protoplasm, and a low viscosity is strongly suggestive of a sol, or at least does not suggest a gel state. Such statements as "The living endoplasmic substance is a very dilute and apparently homogeneous gel," and "This structure (the jelly surrounding the egg of *Asterias*) has a low viscosity for a gel and is therefore extremely dilute," are inexact and can

only lead to misinterpretations regarding the true viscosity of protoplasm.

It is very probable that much of the unfavorable criticism of KITE's work is due, not to faulty observations, but to his lax use of the term gel. For example, GARREY (10) claims that the perivitelline space of a fertilized echinoderm egg is filled with a liquid and not with a gel as KITE (according to GARREY) maintains; but who is to decide that the liquid which GARREY sees is not the same kind of substance which KITE saw if gel means one thing to KITE and another thing to GARREY? Sol and gel should be used with great caution in describing the physical state of matter when one is dealing with an emulsion. It is better to give some idea of the viscosity of the substance and let that suggest a possible sol or gel state. It is well to emphasize the fact that protoplasm is not a simple two-phase colloidal system, as one is led to believe from reading much of the literature. On the contrary, it is a multiphase system, emulsion within emulsion.

General viscosity values of protoplasm

The viscosity of protoplasm is not fixed, for it varies in different organisms, in the same organism at different times, and even in different regions of the same organism at the same time. Furthermore, the viscosity of the constituent parts of the protoplasm (the matrix and the protoplasmic inclusions) may differ from the viscosity of the protoplasm as a whole, and from each other. The examination of an inactive Myxomycete plasmodium will frequently reveal a ground substance of very low viscosity, while the mass of protoplasm as a whole is of high consistency. This relation between the viscosity of the constituents of an emulsion and that of the emulsion as a whole is very evident in certain artificial emulsions. For example, in a dispersion of gelatine the viscosity of the medium (water) at 20° C. is 0.012, while the viscosity of the emulsion, of only 2 per cent concentration, is three times as great (0.037).[6] The most striking example of the high consistency of an emulsion as compared with the low viscosity of its dispersion

[6] This reading (from TAYLOR 27) seems surprisingly low, since a 2 per cent concentration of gelatine will ordinarily set into a jelly at a room temperature of 18° C.

medium is the case of castor-oil soap, a 0.1 per cent concentration of which is an almost solid jelly (**21**).

Thus is it seen that in giving viscosity values it is necessary to distinguish between protoplasm as a whole and its constituent parts, especially the matrix (hyaloplasm). I prefer to use the term matrix rather than hyaloplasm, owing to the confusion which exists in the use of the latter word. Hyaloplasm, as first used by HANSTEIN (**11**), designated "the homogeneous ground substance" of protoplasm as distinguished from the granules suspended in it. Homogeneity of the ground substance, however, is not definitely established. CHAMBERS (**6**) and WILSON (**27**) have employed hyaloplasm to mean the "interalveolar substance." WILSON (**29**), however, admits the possibility of using the word in the exactly opposite connotation; that is, the ground substance (also termed cell sap, enchylema, hyaloplasm, etc.) is the "alveolar substance" which fills the alveoli. If we accept BÜTSCHLI'S (**4**) contention that the hyaloplasm (the peripheral granular-free border) of Myxomycetes is not homogeneous, but is of a definite alveolar structure, then this hyaloplasm must be regarded as including both phases of the emulsoid structure; that is, as consisting of interalveolar and intraalveolar substance.

Material

The data upon which the following discussions are based were obtained by a study of a considerable variety of material. Consequently, the conclusions reached may be regarded as rather generally applicable. Since prominent dissimilarities do occur in the properties of widely differing and sometimes of closely related genera, however, it is to be understood that the statements made refer only to the organism under discussion at the time, although many of the general deductions apply to the protoplasm of all the organisms worked upon, if indeed they are not applicable to all living substance.

The following types are the chief ones which were used for this study: the Myxomycetes *Ceratiomyxa*, *Badhamia*, *Arcyria*, *Cribraria*, and *Fuligo;* the rockweed *Fucus;* the fresh water algae *Spirogyra* and *Vaucheria;* the bread molds *Rhizopus* and *Zygorhynchus;* pollen tubes of the blue-flag *Iris versicolor*, of the beach-

pea *Lathyrus maritimus*, and of the dog's-tooth violet *Erythronium revolutum;* the protozoa *Amoeba* and *Euplotes;* the sand-dollar *Echinarachnius;* and the sea-urchin *Tripneustes esculentus*.

The experimental work on these forms was done mostly in the Botanical Laboratory of the Johns Hopkins University. The work on *Fucus*, *Echinarachnius*, and part of that on Myxomycetes and pollen tubes was carried on at the Harpswell Laboratory, South Harpswell, Maine.[7] The work on *Tripneustes* was done at Ocho Rios, Jamaica, B.W.I.[8]

I am greatly indebted to Professor DUNCAN S. JOHNSON for first pointing out to me the possibilities of microdissection as applied to the study of living protoplasm, and for assistance during the progress of this work. To Professor ROBERT CHAMBERS of the Cornell Medical College, New York City, my thanks are due for many suggestions relative to microdissection. I wish also to acknowledge the help received from Dr. CHARLES V. TAYLOR pertaining to the structure and behavior of the protozoan *Euplotes*, and from Dr. HOWARD E. PULLING, then of this university, pertaining to problems in physical chemistry. To Professor WARREN K. LEWIS of the Medical School of this university I am indebted for the loan of the microdissection instrument used in this work.

Myxomycetes

The consistency of Myxomycete protoplasm when in the active vegetative state is liquid (v.v. 3). One is quite likely to be misled by the apparent ease with which a needle traverses protoplasm into believing that the protoplasm is of watery consistency. Superficial observation of streaming protoplasm also leads one to believe that it must be very liquid, while, as a matter of fact, it may be rather viscous, as in bread mold. A good indicator of the degree of viscosity, when the protoplasm is of low consistency, is the distance from the path of a moving needle at which granules are disturbed. The presence of Brownian movement suggests a low consistency.

[7] I am indebted to Director J. S. KINGSLEY for the use of a room at the Harpswell Laboratory.

[8] To FRANK CUNDALL I am greatly obliged for his kindness in placing the facilities of the Institute of Jamaica at my disposal.

The density of the quiescent plasmodium is very high, possessing a maximum viscosity value of 8, and at times approaching the consistency of a gel, but not possessing the firmness of a rigid gel, for the protoplasmic mass of a quiescent Myxomycete is poorly resilient, although quite tough and elastic, and often possessed of a somewhat plastic quality, in this respect closely resembling bread dough. One prominent characteristic of Myxomycete protoplasm is that it is extremely glutinous. This is in striking contrast with marine ova, the protoplasm of which is not noticeably mucilaginous. As a Myxomycete prepares to fruit, the protoplasm increases in viscosity, until it becomes of gel consistency.

Very frequently a tear in a highly viscous, inert plasmodial mass will cause the formation of a rapidly enlarging protrusion. The liquid which flows into and increases the size of such a globule is a granule-free, hyaline substance, to all appearances identical with the peripheral hyaloplasm, but its origin is not peripheral, for this flow of translucent fluid has its source within the protoplasmic mass. Such behavior seems to favor LEYDIG'S conception of the structure of protoplasm, namely, a framework of spongioplasm permeated by a more liquid hyaloplasm (enchylema). By the use of pressure REINKE and RODEWALD (4) obtained 66 per cent of fluid enchylema from the plasmodium of *Aethalium*. The nature of this exuded liquid substance from a plasmodium cannot be stated with certainty. It appears to be the matrix in which the protoplasmic granules are imbedded, or, more accurately, the enchylema (interstitial substance), since the protoplasm is in the gel state and probably of sponge structure.

Amoeba

In many respects *Amoeba* closely resembles the slime molds. Both organisms have periods of motility and non-motility. The former period is characterized by protoplasmic streaming and the formation of pseudopodia, and by a rather liquid condition of the protoplasm; the latter, by protoplasm that is quiescent and more viscous. Both types of organisms are also differentiated into three more or less distinct regions, namely, the inner less viscous

endoplasm, the outer more viscous ectoplasm, and the peripheral highly viscous protoplasmic membrane.[9]

The flowing endosarc of an active *Amoëba* is of slightly viscous consistency (v.v. 4). When quiescent, the endoplasm becomes of a rather or even a decidedly viscous density (v.v. 5 or 6), but seldom higher, never in the living condition attaining a gel consistency (encystment would probably be an exception to this). Brownian movement of particles is generally present and very pronounced throughout the endoplasm of an active *Amoeba*. This suggests a liquid condition. In the quiescent protoplasm of an inactive *Amoeba* the number of particles exhibiting Brownian movement is decidedly less and the amplitude of vibration is reduced, which are evidences of an increased viscosity. The viscosity of the ectosarc is much higher than that of the endosarc, and, as in the latter, varies inversely with activity. The most pronounced decrease in consistency of the ectoplasm occurs in the region immediately concerned in pseudopodium formation, that is, at the tip of an advancing pseudopodium. Here, in a rather restricted center, the ectoplasm becomes quite liquid, which condition, of course, is conducive to the making of a pseudopodium. The liquid condition is temporary and brief. The ectoplasm not directly taking part in amoeboid movement is of very viscous consistency (v.v. 8).

Investigators generally recognize the high viscosity of the ectosarc of *Amoeba*. For example, JENNINGS (**14**) says that the ectosarc shows "the characteristics of matter in the solid state of aggregation," and HYMAN (**13**) concludes that the ectoplasm is a gel, "semi-rigid and more or less solidified." The latter, however, although recognizing the possibility of "real fluidity" of the "surface layer," goes too far when assuming that the ectoplasm may attain "extreme solidity." This conclusion is apparently based in part on KITE'S (**15**) statement that "little difficulty is experienced in cutting it (the ectoplasm of *Proteus*) into pieces as small as the limit of microscopical visibility." Here (as in the

[9] Some observers would restrict this differentiation to two regions, not recognizing a distinct protoplasmic membrane.

case of the cytoplasm of the *Asterias* egg which KITE describes as "a quiet translucent gel . . . . which can be cut into small pieces") KITE was either dealing with dead protoplasm, or else the expressions used convey an impression which he himself did not mean. In none of the material worked upon have I been able to "cut" the living protoplasm into small pieces.

There is no doubt that when one is able to cut protoplasm "into pieces as small as the limit of microscopical visibility," the protoplasm is no longer normal. It is not clear just what degree of viscosity KITE wishes to attribute to the ectosarc of *Amoeba*. He states that "this living substance has a moderately high viscosity," but he also says that it is a "quite concentrated gel" (p. 155). KITE'S use of the term gel is very broad. The nearest approach to a firm gel condition of the protoplasm which I have studied is that of the ectosarc of the ciliate *Euplotes* and the quiescent protoplasm of bread mold, but even here the protoplasm possesses considerable plasticity, and, although holding its shape when freed, is of soft rather than solid consistency.

HYMAN credits CHAMBERS with confirming these results of KITE. This is not altogether true. To be sure, CHAMBERS (**5**) does say that "the external surface of the egg is a gel," and that the surface layer of marine ova is directly comparable with the "rigid ectoplasm" of Protozoa; but he nowhere states that normal living protoplasm can be cut into small pieces. Quite the contrary, he calls attention to the fact that it is the protoplasmic "coagulate" (and a coagulum, as HYMAN points out, is "incompatible with life") that can be "cut into pieces which hold their shape"; and adds that this is likely "to lead one to the erroneous conclusion that the substance of a cell is usually a solid protoplasmic gel." It is true, however, that the ectoplasm of *Amoeba*, when not immediately concerned in pseudopodium formation, is of high consistency, possessing, as HYMAN says, many properties of solids, such as great elasticity, extreme viscosity, and compressibility; and this is sufficient to support the interesting theory (first advanced by MONTGOMERY, according to MCCLENDON **20**) that amoeboid movement is "due to alterations of the colloidal state" (**13**), that is, it is a solation-gelation phenomenon.

Rhizopus

In the bread mold *Rhizopus* (and *Zygorhynchus*) we have, as in Myxomycetes and *Amoeba*, two general states of consistency, changing from one to the other with changes in physiological activity. The protoplasm in the hyphae of bread mold, in the quiescent state, is of very high consistency. It possesses the greatest viscosity of any living plant protoplasm which I have observed by the aid of microdissection.[10] It is of gel consistency, more usually that of a soft gel (v.v. 9), is sticky, quite elastic, and very extensile, closely resembling bread dough in these physical properties. At times it exhibits some resiliency, and may then be characterized as a rigid gel (v.v. 10). KITE (**15**) has described the living substance of the striped muscle cell of *Necturus* as "the most viscous, elastic, and cohesive of the living gels we have so far considered." The protoplasm of the cells of nerve and muscle tissue is probably of as high a viscosity as any living animal plasma; but it must not be concluded from these observations that this gel consistency is necessarily permanent. Nerve and muscle protoplasm probably exist, just as all the protoplasm so far considered exists, in the sol state at times. Indeed, certain theories of muscle contraction based on "a temporary redistribution of the more fluid portion of the tissue" (LILLIE, **18**), and on "coalescence (incipient coagulation) of colloidal particles," which is reversed during the relaxation phase (**17**), demand a varying viscosity of muscle cells.

Ordinarily, when a filament of bread mold is torn the inactive protoplasm will not flow out, but when pressure is exerted by a needle some distance back from the torn end, the gelled protoplasm can be forced out in the form of a rod, just as one would squeeze oil paint from an artist's tube, and this rod maintains its shape until disturbed.

The streaming protoplasm of *Rhizopus*, as one would expect, is considerably less viscous than the quiescent protoplasm, but it

[10] The viscosity of plant protoplasm which is undergoing long periods of rest, for example, that of seeds, is undoubtedly of even greater concentration, for here the water content is reduced to 20 per cent, while in protoplasm in which pronounced metabolic processes are going on the percentage of water is 80 or more.

is not of as low viscosity as it superficially appears to be, and by no means closely approaches the very liquid state of the endoplasm of an active *Amoeba*. In its most fluid condition it is of at least a rather viscous consistency (v.v. 5), while, when slowly streaming, it may be of very viscous consistency (v.v. 7). All gradations exist between the rather viscous condition when streaming and the gel state when quiescent.

Increase and decrease in viscosity of protoplasm in *Rhizopus* are probably dehydration and hydration phenomena. It is interesting to appreciate the extreme rapidity with which these changes may take place. The streaming protoplasm, by pressure of a needle sufficient to close a hypha, may be made to assume instantly such a consistency that not only does streaming cease, but on subsequent tearing of the filament the emptying of the thread is prevented. Choking of the hypha has caused gelation of the plasma, probably through dehydration. Later, without further disturbance by needles, there is a reversal of the phenomenon. Solation takes place (apparently hydration has set in) and the protoplasm of itself flows out of the torn filament.

Euplotes

In the ciliate *Euplotes* there exists a differentiation between endoplasm and ectoplasm more marked than in any other instance of which I am aware. The endoplasm is very liquid, while the ectoplasm has the firmness of a rigid gel. The former consists of a dilute matrix in which a great variety of inclusions are suspended, from minute protoplasmic particles to whole Protozoa taken in as food; while the latter is free of minute granules (microsomes), and presents a beautiful alveolar structure with the characteristic surface alveolar layer. So far as my limited observations on this protozoan go, the very liquid condition of the endoplasm and the gel state of the ectoplasm seem to be constant. I have observed no change from sol to gel and vice versa, nor any appreciable increase or decrease in viscosity. That there must be some such change at division of the organism (for example, solation of the rigid ectoplasm) seems a physical necessity.

Marine ova

The fully mature, normally discharged eggs of *Fucus* are decidedly viscous (v.v. 6). The unripe eggs are of lower viscosity. The properties and behavior of the ova of *Echinarachnius* and *Tripneustes* are so similar that they can be considered together. The consistency of the mature unfertilized eggs of *Echinarachnius* and *Tripneustes* is a trifle higher than the protoplasm of *Fucus* ova, but barely of very viscous consistency (v.v. 7). KITE has described the cytoplasm of the *Asterias* egg as "a quiet translucent gel." CHAMBERS (5) calls attention to the fact that KITE's paper "is a pioneer one in microdissection research. The observations recorded were necessarily fragmentary." KITE was probably dealing with degenerate gelated protoplasm, or else he fully appreciated the true viscosity of the normal protoplasm of an echinoderm egg and has erroneously described it by his loose use of the term gel. CHAMBERS (6) states that "the interior cytoplasm of a marine egg is a viscous fluid. The viscosity is high enough to prevent any Brownian movement of the inclosed granules." Since the expression "viscous fluid" holds no place in a scale of viscosity, nor is it compared with any other commonly known substance, it is not quite clear just how viscous is the living viscous fluid of a marine egg. The minimum viscosity which the absence of Brownian movement (a criterion used by CHAMBERS) will permit is apparently the viscosity of concentrated laboratory glycerine. EXNER, according to LEHMAN (16), found that "the concentration of ordinary commercial glycerine (specific gravity 1.21) was just enough to put a complete stop to the vibration." A very slight dilution of concentrated glycerine (specific gravity 1.25) is sufficient to permit a noticeable Brownian movement of suspended carmine particles. If Brownian movement is impossible in a very viscous substance such as glycerine, which has a viscosity value of 7, then protoplasm in which no Brownian movement is evident must apparently possess a consistency of about this value. It is such a viscosity value (between 6 and 7) which I attribute to echinoderm ova.

Viscosity of nucleus

CHAMBERS (5) states that the resting nucleus of marine ova "exists in the sol state," and describes how it can be pinched into two droplets which run together on coming into contact. KITE (15) says of the viscosity of the nucleus of the starfish egg: "With the exception of the nucleolus, the nuclear substance is all in the sol state." Of the nucleus of *Amoeba proteus*, however, he says: "The whole of the nuclear substance is a highly rigid and granular gel, the minutest pieces of which show no appreciable change when dissected out in distilled water."

Although one must be very cautious in assuming that all protoplasm is possessed of the same physical properties as that particular protoplasm examined, yet on general principles it would seem that it is hardly likely that the nucleus of an ovum is very liquid (that is, a sol), and that of *Amoeba* a highly rigid gel. My observations on the nucleus of *Amoeba* show that its viscosity is also low, as is the viscosity of nuclei of marine ova (as stated by KITE and CHAMBERS). Results based on the examination of isolated pieces of protoplasm are very uncertain, and that minute pieces of the nuclear substance undergo no change when dissected out into water is quite untenable.

The nucleus of *Amoeba* is rather liquid, but by no means watery, for it possesses a slight degree of viscosity. It is apparently in the sol state. The nucleus when freed from the organism increases in consistency, sometimes slowly and sometimes rapidly. The extremely viscous and in all probability partially degenerate substance of an isolated nucleus is very coherent and elastic, capable of being stretched into fine, barely visible threads. Ultimately the isolated nucleus degenerates into a granular coagulum.

Changes in protoplasmic consistency

While protoplasm may be more or less permanently of a definite viscosity (in such forms as *Euplotes*), yet it does undergo reversible changes. For example, the ectosarc of *Amoeba* is characteristically of a high consistency, yet at the tip of an advancing pseudopodium it becomes temporarily very liquid. Also, in Myxomycetes and bread mold the quiescent protoplasm is very

dense, while the streaming plasma is much more dilute. The change from one state to the other is dependent upon (or at least coincident with) physiological (or physical) activity.

The changes in consistency so far considered have had to do only with the one phenomenon of streaming. There are several other factors which bring on changes in protoplasmic consistency, however, such as development (growth), reproduction, mitosis, and pathological conditions. These changes may be in one direction only, and relatively permanent, as the change from a liquid state to a highly viscous one in the process of fruiting in Myxomycetes; or they may be periodic and reversible. The latter type is exemplified in the changes which accompany streaming. Of the former type the gradual increase in consistency during development of the egg of *Fucus* is an example.

DEVELOPMENTAL CHANGES IN VISCOSITY.—The developmental change in viscosity has been fully described in my former publication (**23**). The protoplasm of young uninucleate oogonia is of liquid consistency (v.v. 3). I think this value is more accurate than the "very liquid" one given in the former publication referred to. Nearly mature oogonia, in which division into 8 eggs is just complete, are of slightly viscous consistency (v.v. 4). As the eggs near maturity they increase to the rather viscous stage (v.v. 5), and the fully mature, normally discharged egg is decidedly viscous (v.v. 6). It is interesting to note that this progressive increase in consistency is coincident with a decrease in physiological activity. The young oogonium with protoplasm of liquid consistency is in a state of active growth, while the decidedly viscous ripe egg is in a more or less quiescent state awaiting fertilization.

REPRODUCTIVE CHANGES IN VISCOSITY.—I have already referred to the increase in viscosity of a Myxomycete plasmodium as it prepares to fruit. The liquid density (v.v. 3) of the active vegetative stage becomes, when inactive, extremely viscous (v.v. 8), and, on preparing to fruit, increases to a gel consistency.

CHANGES IN VISCOSITY DURING MITOSIS.—Division following fertilization in marine ova brings on very decided changes in viscosity. Earlier work on the ova of *Fucus* gave evidence of a marked decrease in consistency of the egg protoplasm within half

an hour after fertilization. Subsequent work on marine animal eggs has shown that the change in viscosity due to fertilization is not so simple a phenomenon as one might think from what can be observed in dissecting the egg of *Fucus*. The protoplasm of the ripe unfertilized egg is of comparatively uniform viscosity. Division, following fertilization, brings on pronounced regional differences in consistency. In the egg these differences are wholly obscured by the dense color of the chloroplasts.

The changes in protoplasmic consistency which are a consequence of fertilization can readily be determined in the dividing echinoderm egg. The following data were obtained principally from dissection of the ova of *Tripneustes*, but were in great part substantiated by subsequent work on the ova of *Echinarachnius*. My observations on the viscosity of the echinoderm egg during mitosis are less detailed than those of CHAMBERS (**6**). In brief, CHAMBERS finds that the sphere (the central transparent area of the aster of the mitotic figure) and the astral rays consist of a clear liquid of very low viscosity, while the surrounding cytoplasm is in the gel state, and that there is a "periodic reversal of the sol to the gel state and vice versa" during mitosis. The following data support, in the main, these findings of CHAMBERS.

The mature unfertilized sea-urchin egg is very viscous (v.v. 7) and comparatively uniform in its viscosity. Following fertilization a change in consistency soon takes place. With the first appearance of the aster there is an increase in viscosity of the peripheral cell cytoplasm. By peripheral protoplasm I refer to a broad outer zone as distinct from an inner core, and not to an ectoplasmic layer, a membrane, or the like. This increase in consistency of the general peripheral protoplasm is from the very viscous to the exceedingly viscous state. With the first appearance of the amphiasters there is a pronounced decrease in viscosity of the central region of the cell, and this condition is maintained throughout the intermediate stages of divisions (from middle prophase to late anaphase). Close examination shows that the dilute protoplasm in the center of the mitotic figure makes up the hyaline area surrounding each pole (the "hyaloplasm-sphere" of WILSON **28**).

The rays of the amphiasters, like the two polar spheres, are apparently also of dilute protoplasm. This thin hyaline substance which makes up the astral rays and polar areas is of liquid consistency (v.v. 3). Although quite dilute it is not watery. In connection with the low viscosity of the hyaline rays it is interesting to recall the theories which have been advanced pertaining to the flow of the substance of which the rays are composed. AUERBACH was probably the first to advance the theory that the rays were currents of a protoplasmic substance. Others, notably FOL, have advocated a similar theory. WILSON (**28**) likewise upholds this theory with the statement that "no one . . . . can, I think, doubt that such a centripetal movement occurs, or that the clear hyaloplasm flows inwards to form the growing hyaloplasm-spheres." STRASBURGER (**24**) states that he, with FOL, looks upon the astral rays as "centripetal currents," to which STRASBURGER ascribes the function of "carrying to the astral body substance which serves as nourishment for the new nucleus."

The protoplasm peripherally located, and also that making up the wedge-shaped protrusions which alternate with the hyaline rays and thus give to the mitotic figure its starlike appearance, is all of high consistency, being very or extremely viscous (v.v. 7 or 8).

A very convincing demonstration of the fluidity of the substance of which the astral spheres and rays are composed was obtained through dissection and previous vital staining with neutral red. The eggs were placed in a very weak stain of neutral red at the time they were fertilized, and allowed to remain in the stain during division, which requires about an hour. The clear liquid substance of the spheres and rays stains a brilliant pink, while the surrounding highly viscous granular plasma takes on little if any stain. A stained ovum in the early anaphase of mitosis was torn until a small globule of protoplasm adjoining the egg had been formed. By pressure against the egg the protoplasm from it could be forced into the globule, thus enlarging the latter, and then by pressure against the globule the protoplasm could be forced back into the egg. The protoplasm which could thus again and again be made to flow from the egg into the globule, and vice versa, was the stained hyaline liquid substance of the astral

spheres, and its fluid condition as contrasted with the extremely viscous consistency of the peripheral protoplasm was very noticeable. It was also strikingly evident that the clear liquid substance did not mix with the granular protoplasm during several minutes of kneading of the egg contents.

The interesting question arises, What is this clear liquid substance which makes up the astral polar areas and rays? WILSON (**27**) refers to it as hyaloplasm (matrix).[11] CHAMBERS (**6**) is noncommital and refers to the contents of the sphere "as the sphere substance or sphere liquid." If the sphere and ray substance is hyaloplasm (matrix), it is very likely a modified, and perhaps greatly modified, form of it, and therefore strictly not hyaloplasm. The unusual circumstances under which it is produced rather suggest that it is at least a modified form of the matrix. This same question arose concerning the identity of the exuded globules of clear substance from Myxomycete plasmodia. Whether the sphere substance is a secretion, which does not seem likely, or an extravasation of one of the many complex phases of the living colloidal system cannot be determined.

With the coming of the telophase of mitosis and the disappearance of the aster, the viscosity of the central protoplasm of the egg rises from the low value of the sphere substance (v.v. 3) to a viscosity value of 6, and with the completion of division we have in each daughter cell of the embryo a general protoplasmic consistency identical with that of the egg before fertilization (v.v. between 7 and 8).

PATHOLOGICAL CHANGES IN VISCOSITY.—The changes in viscosity so far considered have all been of living and normal protoplasm. In determining degrees of viscosity of protoplasm it has been necessary to guard carefully against misinterpretations due to the readiness with which protoplasm alters its consistency as a result of dissection and aging, both of which bring on pathological changes which inevitably result in an increase in viscosity.

[11] "The substance thus flowing inwards I shall for the present designate simply as hyaloplasm (equivalent to the 'cyanoplasm' of MORGAN), and I believe it represents wholly or in part the interalveolar or continuous substance lying between the alveolar spheres"—(WILSON **27**).

Prolonged dissection always ultimately causes an increase in the consistency of protoplasm, unless rapid dissolution first takes place. The rate of increase in viscosity varies greatly in different types of organisms, and even in different individuals of the same type. It is surprising how much dissection protoplasm will often tolerate without showing any increase in viscosity or sign of degeneration, but no protoplasm will endure churning by microdissection needles indefinitely. The outcome of such ill treatment may be rapid disintegration or a pronounced increase in viscosity, probably gelation. HYMAN (13) states that "the injury of cutting may completely alter the physical state of protoplasm, probably in the direction of liquefaction." This is not true unless the injury is sufficient to cause complete degeneration, that is, death. Injury not resulting in death always causes an increase in viscosity of the protoplasm. In the advent of death liquefaction does first take place, followed by coagulation.

The injury to an organism undergoing dissection may be general or local; in either case an increase in viscosity results. If the increase in consistency is local, the injured region may be discarded, apparently by the organism, although actually the living organism plays only a passive part, or it may be reabsorbed, by reverting to the sol state. If the increase in viscosity is general and pronounced, death follows.

An *Amoeba* usually shows little change in viscosity over that of the normal quiescent stage as a result of quite some minutes of dissection. Finally, however, either a sudden and pronounced gelation takes place, or, more often, rapid disintegration results. In Myxomycetes the rate of change in consistency due to physical disturbance is slow and gradual. Ultimately, protoplasm subjected to much dissection will always coagulate, unless preceded by rapid dissolution. A coagulum thus formed at death can be cut up into pieces which exhibit none of the properties of the living substance, such as glutinosity, plasticity, elasticity, etc.

Marine ova are subject to the same pathological changes in viscosity as a result of dissection and aging. The increase in consistency from dissection takes place more rapidly than in Myxomycete protoplasm. Here again the degenerate protoplasm ultimately

coagulates (rapid or slow dissolution may follow as well as precede coagulation). The coagulum is coarsely granular in appearance, suggesting a granular precipitate.

Brownian movement of protoplasmic particles

It is rather surprising how little the presence of Brownian movement of particles in really living protoplasm is appreciated. It is usually said that protoplasm, because of its comparatively high viscosity, will not permit Brownian movement of its particles, and that only in vacuoles, whose contents is a dilute sap, is Brownian movement of particles to be observed in a living cell. The classical example of this is the terminal vacuoles of the desmid *Closterium*. It must be borne in mind that I have reference here only to microscopically visible particles, such as make up the granular plasm, and not to ultramicroscopic colloidal particles which are in a constant state of vibration in probably all liquid protoplasm. When workers refer to "the Brownian movement of particles" (2) contained in protoplasm, they do not always explain whether the reference is to microscopic or ultramicroscopic particles. Usually it is apparently the latter. Brownian movement of suspended microscopic particles in protoplasm cannot be seen in by any means all cells or organisms, but it is to be observed in the dilute endoplasm of some ciliates, in the liquid protoplasm of streaming Myxomycetes, and to a striking degree in one of the most studied of organisms, *Amoeba*.

In a quiescent *Amoeba* the number of particles exhibiting Brownian movement is small, and the amplitude of the movement is short. In an active *Amoeba*, the protoplasm of which is more dilute, all particles except the largest droplets exhibit Brownian movement, the motion varying inversely as the size of the particle ($4\ \mu$ seems to be the maximum size of particles capable of the vibration, according to YOCOM 30), and the amplitude of vibration is relatively large. In the liquid endoplasm of the ciliate infusorian *Euplotes* the suspended particles are frequently in a state of vibration, especially when cyclosis is taking place.

The protoplasm of *Amoeba* in which Brownian movement is to be observed is of rather liquid consistency, and when this proto-

plasm increases in viscosity coincident with a decrease in activity, both the number of particles exhibiting Brownian movement and the amplitude of vibration are lessened. This fact is expressed in the physical law which states that the amplitude of vibration of a particle of a given size is inversely proportional to the viscosity of the dispersion medium (**8**). This law is further supported by the fact that in highly viscous living protoplasm no Brownian movement is to be seen.

Brownian movement of particles is so characteristic a phenomenon of degenerate protoplasm that I was led to look upon it as an "unfailing criterion of degeneration" (**23**). Such a conclusion, in view of the presence of Brownian movement in living protoplasm, is not justifiable. It is true, however, that one of the first signs of degeneration in protoplasm, which in the living normal condition shows no Brownian movement, is the instant assumption of a marked oscillating motion of the protoplasmic particles. The surprising thing, however, is that this Brownian movement is actually taking place in an apparently highly viscous mass. Careful dissection will reveal the fact that the degenerate protoplasm has gelated only at the surface, sometimes to an appreciable depth, while the interior of the mass is very dilute. It is in this watery degenerate protoplasm that the suspended particles are in vibration.[12] Death, therefore, has resulted in a liquefaction, probably due to excessive imbibition of the protoplasm. This fact is not generally realized, primarily because the watery condition is only temporary, since ultimately the whole of the protoplasm becomes a rigid coagulum. GAIDUKOV (**9**), for example, in describing the death changes which take place in the living emulsion, says that "with death of the plasma a coagulation results, which in the case of slow death, is a precipitation, and of sudden death (by fixation), a congealing." I wish again to emphasize the fact that this liquefaction of the protoplasm is a consequence of death, and not of mere injury. Injury, not resulting in death, invariably produces an increase in viscosity. It is not true, therefore, that Brownian movement of microscopic particles in protoplasm ends with death (**2**). On the contrary, it is

[12] Diffusion of the dilute protoplasm is prevented by rapid gelation at the surface.

frequently set up as one of the consequences of a death phenomenon, that is, temporary liquefaction. When GAIDUKOV states that at death "the motion of the particles ceases," he undoubtedly has reference to ultramicroscopic colloidal particles, and even here this cessation of motion must sometimes be the ultimate and not always the immediate result of death.

The consistency of concentrated laboratory glycerine (specific gravity 1.25) is just high enough to prevent a visible vibration of carmine particles suspended in it. It is not always evident that the viscosity of living protoplasm in which no Brownian movement is to be seen is as high as that of concentrated glycerine. As a general rule, however, it can be stated definitely that protoplasmic particles in a medium of high consistency are not in vibration, while those in very liquid protoplasm are. As a criterion of the viscosity of protoplasm as a whole I do not regard the occurrence or non-occurrence of Brownian movement as very accurate or conclusive.

Summary

1. Protoplasm is a polyphase emulsoid system.

2. Physical structure and not viscosity determines the sol or gel state of an emulsion. Consequently, while protoplasm undoubtedly exists sometimes as a sol and sometimes as a gel, yet sol and gel as descriptive terms of the physical state of protoplasm must be used with great caution when viscosity is the only criterion.

3. The viscosity of protoplasm ranges from a degree slightly more than that of water to the firmness of a fairly rigid gel.

4. While a certain degree of viscosity may characterize the protoplast as a whole, the latter is always more or less divided into regions, whether larger general protoplasmic regions such as ectoplasm and endoplasm, or smaller localized centers of protoplasmic activity such as nucleus and chromatophores, which differ in viscosity from the protoplasm as a whole.

5. Some protoplasmic regions do not noticeably vary in their consistency, but the viscosity of a protoplast as a whole generally varies considerably within a rather wide range.

6. Some of the factors influencing changes in protoplasmic consistency are periodic changes in physiological activity, development, reproduction, mitosis, injury, and death.

7. Streaming protoplasm is less viscous than quiescent protoplasm.

8. Young active protoplasm increases in viscosity as it matures and becomes less active.

9. As a Myxomycete plasmodium prepares to fruit, its consistency becomes very high.

10. During mitosis there are very marked regional changes in viscosity.

11. Physical disturbance usually causes a pronounced increase in viscosity, although the rate of increase varies greatly in different individuals.

12. At death protoplasm frequently becomes temporarily very dilute, probably the result of excessive imbibition. Ultimately the degenerate protoplasm coagulates into a solid granular mass, if rapid dissolution has not preceded coagulation.

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GROUPING AND MUTATION IN BOTRYCHIUM

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CHARLES J. CHAMBERLAIN

(WITH ELEVEN FIGURES)

Ever since the appearance of CHRYSLER'S[1] paper, claiming that the fertile spike of *Botrychium* represents a pair of fused pinnae of the vegetative leaf, I have been interested to note the peculiarities in the spore-bearing portions, upon which he relies for a part of his evidence. Two fertile spikes in the position of the lower pair of leaflets, spikes in which the two component leaflets are incompletely fused, sporangia on the second pair of leaflets in addition to the sporangia of the fertile spike, and occasional sporangia on vegetative leaves were found during vacation field studies of *Botrychium obliquum* and its varieties. CHRYSLER'S claim needs no support, his evidence both from field study and anatomy being so convincing that, for years, we have treated these forms as a mere family, Ophioglossaceae, under the Filicales.

However, the field studies, carried on for several years during September vacations in Ohio, at Oberlin, Sullivan, Cleveland, and Birmingham, together with a few observations at Osborn, Indiana, and at Fort Sheridan, Illinois, impressed upon me that one scarcely ever finds isolated plants of *Botrychium*. They are almost invariably grouped; even when there seems to be an isolated plant, others can usually be found in the immediate vicinity.

In *Ophioglossum* there is abundant vegetative propagation by branching of the rhizome, so that not only are the plants grouped, but the plants of a group are more or less connected. In striking contrast, *Botrychium* shows no vegetative propagation. The rhizome scarcely ever branches and, when it does, the branch is not likely to become separated and form a new plant. Every plant comes from a prothallium. Consequently the distribution is

[1] CHRYSLER, M. A., The nature of the fertile spike in Ophioglossaceae. Ann. Botany 24: 1–18. 1910.

entirely by spores; and since the prothallia are of the subterranean tuberous type, with an endophytic fungus, the prothallia develop only when the conditions for this rather unusual mode of development are present.

How far the spores might be carried is problematical. The grouping of plants indicates that most of the spores are not carried far, but when a plant is once established it becomes the center of a group.

At first I was interested only in the fact of grouping and in the size of the groups of *Botrychium obliquum* and *B. virginianum*. It was noted immediately that the groups of *B. virginianum* contained many more plants than those of *B. obliquum*, and that the groups were more closely associated. In counting plants and making plots, one soon learns to find specimens, especially the smaller ones, which easily escape notice, and the number of plants in a group is likely to be surprisingly larger than the average botanist would have guessed from a cursory examination.

The most closely associated groups, with the largest number of plants in a group, were found at the borders of rather open woods. Plants in the deeper woods, although likely to be large and vigorous, are not abundant.

During the Septembers of the past four years the grouping was observed, and a searching for prothallia developed some facility in recognizing young plants. In 1918 the plants of many groups were counted, especially at Sullivan, where *Botrychium* is exceptionally abundant; and in 1919 plots were made, showing not only the number and position of plants in a group, but also the relation of the groups to each other.

Botrychium virginianum is more abundant than *B. obliquum*, even when the two species are growing together under the same conditions. On the eastern border of a densely wooded tract at Sullivan, Ohio, where *B. virginianum* is more abundant than I have ever seen it in any other locality, prothallia were collected and observations were made for several years. The border of the woods is roughly marked by a rail fence, with but few trees on the eastern side and some trees removed on the western side, so that the woods end in what farmers call a "clearing." The plants and

prothallia are most abundant in the clearing, within 25 m. of the fence, becoming more and more scattered as the woods become denser, while at a distance of 200 m. west of the fence scarcely any plants are found. In this place plants are most abundant on little elevations caused by uprooted trees. When a large tree is blown down, the roots tear up a considerable quantity of soil, so that when the tree decays and disappears there remains a mound with a depression on one side of it. These little mounds of clay soil, scantily covered by moldy humus, seem to be exceptionally favorable places for the germination of spores and the growth of plants.

A few years ago, before any plots were made, the abundance of plants in this locality suggested counting the number on definite areas. These areas do not correspond exactly to the groups which were plotted later, because only the denser centers of the groups were considered, the more scattered plants at the borders being omitted. Some of the highest countings of plants on given areas are worth recording. On areas of 1 sq. m. there were 15, 20, 29, 30, 31, 42, 66, and 106 plants. In the last case the plants were very closely crowded, one cluster of 5 plants occupying a space only 3 cm. sq. On areas of 2 sq. m., there were counted 27, 43, 70, and 103 plants; on 4 sq. m., 112 plants; on 2 dm. sq., 7, 10, and 16 plants; and on 2.3 dm. sq., 8 and 21 plants.

In this clearing the groups were rather closely associated, being separated from each other by distances of 1–10 m., with only here and there a plant between. Many of these plants were small, some of them sporelings still attached to prothallia; but in any place where *Botrychium* is abundant there will be a goodly number of large plants. In such places white patches of the fungus can be seen by turning over the leaf mold.

Aside from noting the grouping and counting the number of plants in a group, little was done with *B. virginianum*. The same must be said of *B. simplex*, which was discovered accidentally at Osborn, Indiana, during a search for *Ophioglossum*. A group of a dozen specimens of this little *Botrychium* was found on an area of about 1 sq. m. So far as we know, this species has not been reported for the Chicago region.

The principal interest centered in *B. obliquum* and *B. dissectum*, which is often regarded as a variety of *B. obliquum*. There are other forms which taxonomists describe as varieties of *B. obliquum* and which may be as distinct and may have as definite a relation to the parent form as we believe *B. dissectum* has to *B. obliquum;* but we did not make any study of these forms, and in making plots and in counting we recognized only *B. dissectum*, and put all the rest—the varieties *oneidense*, *tenuifolium*, and *elongatum*—under the general name *B. obliquum*. Besides these varieties, which can often be identified with a manual, there are fluctuating variations, so that one who is not a professional taxonomist is tempted to call the whole assemblage *B. obliquum* and let the name cover *B. obliquum* and its derivatives.

B. obliquum does not occur in such large numbers as *B. virginianum*, the plants of a group being more scattered, with seldom more than a dozen plants on 1 sq. m. This difference in numbers and the difference in grouping is indicated in fig. 1. This plot represents an area of 33 by 40 m. The dots and the crosses of the diagram are all of one size, but the plants varied from sporelings still attached to prothallia up to large specimens. Where plants are so numerous, as indicated in the denser groups, not more than a quarter of them have fruiting spikes.

Why plants of *B. virginianum* should be so much more numerous than those of *B. obliquum*, when they are growing in the same situation, particularly when growing on the same spot, as shown in the lower right hand group in fig. 1, is not obvious. A million spores would be a very conservative estimate for the output of an average plant of either species, and in the largest plants the output probably reaches five or six million spores; but a comparison of the number of plants and the number of spores would indicate that far less than one spore in a million produces a plant which can be seen above ground. One might guess that spores which do not sift down immediately to a safe depth die very soon from exposure or only a little later from the winter's cold; but we have noticed that in the tropical rainy forests of southern Mexico, where *Botrychium* is abundant and where there would seem to be no danger from dryness or cold, prothallia are as difficult to find as in the United

States. It may be possible that differences in the sculpturing on the spore coats may facilitate or impede the penetration of the

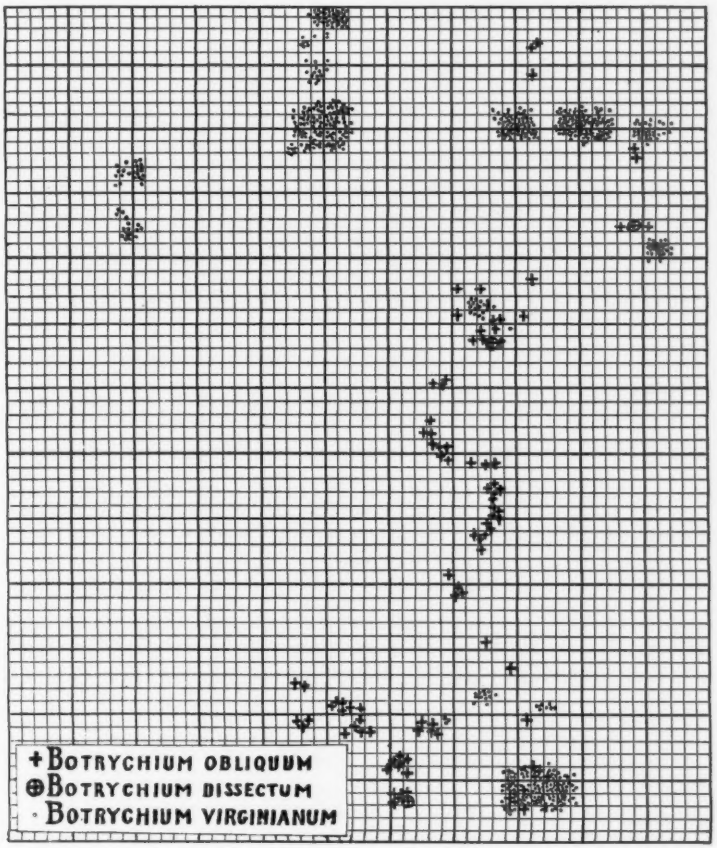


FIG. 1.—Plot 33×40 m. at Sullivan, Ohio, showing *Botrychium virginianum*, *B. obliquum*, and *B. dissectum;* each dot represents a plant of *B. virginianum;* each cross, a plant of *B. obliquum;* and each cross in a circle, a plant of *B. dissectum.*

spores to a favorable depth, or may favor or impede the absorption of water, and thus account for the larger number of plants of *B. virginianum.*

The principal study of *B. obliquum* was made at Oberlin, Ohio, in the cemetery, a part of which is sparsely covered by the original timber, while the rest is still more sparsely dotted with *Juniperus*, *Pinus*, *Thuja*, and *Cupressus*. Of the 24 groups which were counted

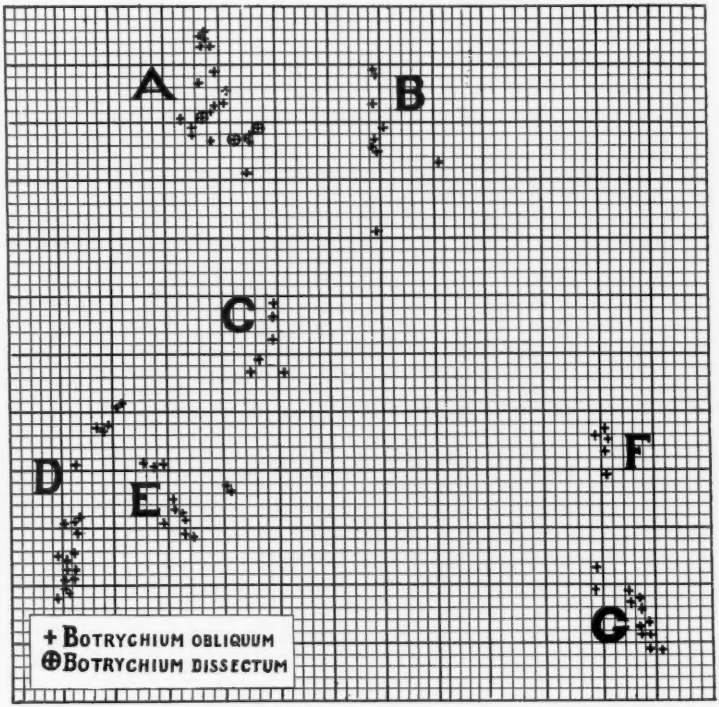


FIG. 2.—Plot about 40×43 m. at Oberlin, Ohio: distances between individual plants of a group approximately correct, but distances between groups *A* and *C*, *C* and *D*, *C* and *F*, and *F* and *G* about twice as great as indicated; there is no *B. virginianum* in this vicinity.

and plotted, 17 were at this place, 4 at Sullivan, 2 at Cleveland, and 1 at Pittsfield. A sample of the plotting at Oberlin is given in fig. 2.

It was from such detailed field studies as those shown in figs. 1 and 2 that we reached the conclusion that *B. dissectum* is a

mutant from *B. obliquum*. In ordinary cases such a conclusion would be tested by sowing the spores and growing the plants; but, so far as we are aware, no one has ever succeeded in raising prothallia of any species of *Botrychium* from the spore. Even if someone should find out how to grow prothallia and sporelings, it would

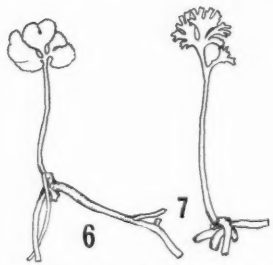
FIGS. 3–5.—Two vigorous plants of *B. obliquum*; plant of *B. dissectum* with typical leaf and roots, but with unusually good sporangia: small plant of *B. obliquum*.

take a long time to secure any results. How long the spore may rest before germinating is problematical; but even after it germinates it is probably a year or more before the prothallium reaches the fertilization stage. In adult plants the leaf is in its fourth year when it appears above ground. Consequently at least five years, and more probably six or eight years, would elapse between the

sowing of the spores and the appearance above ground of the first tiny leaf of the sporeling. We have seen one sporeling with a fertile spike bearing a few sporangia while still attached to the prothallium, but it is probable that ten or twelve years usually elapse between the germination of the spore and the development of a plant up to the spore-bearing stage. During the past twenty years we have made so many unsuccessful attempts to germinate *Botrychium* that we did not even try to test our theory by this method, but collected some circumstantial evidence which supports our conclusion that *B. dissectum* is a mutant from *B. obliquum*.

Before presenting the evidence it is worth while to call attention to the distinguishing characters of the two forms.

B. obliquum and its varieties have oblique leaflets with margins ranging from nearly entire to quite sharply serrate, sometimes doubly serrate, while *B. dissectum* has a leaflet, still oblique in topography, but so dissected that the specific name is very appropriate (figs. 3–5). This difference in leaves is recognizable even in the sporeling (figs. 6 and 7). The leaves of sporelings are simpler in outline than those of larger plants, but the general character of the margins is characteristic from the first, so that there is no danger of confusing the forms.



FIGS. 6, 7.—Sporeling of *B. obliquum;* natural size; sporeling of *B. dissectum;* natural size.

In *B. obliquum* and its varieties there is considerable variation in the shape of the leaflet and in the character of the margin; but, so far as the margin is concerned, the differences are confined to a greater or lesser degree of serration. The deepest serration of *B. obliquum* would not be mistaken for the deeply cut margins of *B. dissectum*. In *B. dissectum* there is also some variation in the margins, but the dissected character is always evident, the differences being in the extent of the dissection (fig. 8).

We are familiar, of course, with the great variations in the leaflets of cultivated ferns, where a single leaf may have leaflets with a nearly entire margin, leaflets deeply cut, and still others so

deeply cut that the bipinnate condition is reached. We do not regard *Botrychium* as a similar case, but believe that the differences in the margins of *B. obliquum* and *B. dissectum* are more like the differences in the margins of the leaflets of *Bowenia spectabilis* and *B. serrulata*, and like the differences in the leaf margins of *Dioon edule* and *D. spinulosum*. In these four cycads, the margins are so constant that they are reliable diagnostic characters.

The short subterranean stem, with the long-stalked leaf and spore-bearing portion with a still longer stalk, is similar in *B. obliquum* and *B. dissectum*.

The roots of *B. dissectum* are wrinkled and fleshy, like those of *B. obliquum*, and not at all like the slender roots figured in BRITTON and BROWN'S *Illustrated Flora*.

In general, *B. obliquum* is a larger plant than *B. dissectum*. At Oberlin the largest plant of *B. obliquum* measured 35 cm. in height, with a leaf 20 cm. in width, and the spore-bearing part of the fertile spike 15 cm. long. While this is not quite up to the limit in size recorded for the species, it is very large, and most individuals are much smaller. One plant of *B. dissectum* measured 28 cm. in height, but this is exceptional. The usual size of *B. dissectum* is about two-thirds that of *B. obliquum*.

FIG. 8.—Leaflets from three plants of *B. dissectum;* natural size.

The most suggestive difference between *B. obliquum* and *B. dissectum* is seen in the fertile spike. The sporangia of *B. dissectum* sometimes look uniform and perfect, but somewhat smaller than those of *B. obliquum*. The difference in size, where the sporangia seem to be perfect, may be seen by comparing *A* and *D* of fig. 9.

However, most specimens show a considerable proportion of abortive sporangia which, even without sectioning, may be distinguished by their smaller size (fig. 9, *B* and *C*). The figure of *B. dissectum* in BRITTON and BROWN'S *Illustrated Flora* is evidently

drawn from a specimen with sporangia like those in fig. 9, *B* and *C*, and in this respect is characteristic.

Sections of sporangia, like those shown in fig. 9, *B* and *C*, show that the smaller sporangia contain no spores at all (fig. 10). In most of these cases the sporangium wall is from 4 to 6 cells thick, with the inner layer not differentiated into a definite tapetum, and the outer lacking the anticlinal thickenings so characteristic of sporangia which produce even imperfect spores (fig. 11). In extreme cases the sporangium is a mere mass of parenchyma cells; in others, a narrow streak of mucilage indicates that sporogenous tissue had begun to form; in still others, like the one shown in

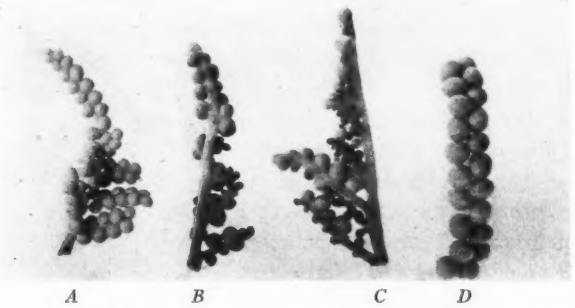


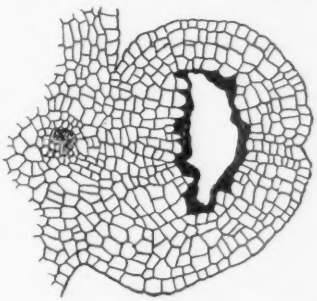
FIG. 9.—*A, B, C, B. dissectum; D, B. obliquum;* ×2

fig. 10, a considerable mass of sporogenous tissue has been formed; and in a few cases it could be seen that the mucilaginous mass consisted partly of imperfect, disorganizing spores.

In the apparently perfect sporangia of *B. dissectum* many of the spores are somewhat smaller than the average size for *B. obliquum*, and there are many spores which look as if they might be abortive. Fig. 11 shows six spores still floating in the tapetal plasmodium. The two spores at the upper left, one of them triangular in outline, are doubtless abortive; of the other four, only the one at the lower left has the full diameter of a normal spore of *B. obliquum*. The epidermal layer has anticlinal thickenings, as in normal sporangia, which dehisce and shed their spores.

It would be interesting to compare the reduction divisions of the two species, but the problem of getting material of *B. dissectum* makes such a comparison difficult, if not impossible. Even with good preparations of critical stages, the interpretation might be uncertain, for, judging by a few figures in *B. obliquum*, the $2x$ number is well over 100, and the chromosomes are tangled and hard to count.

Such evidence as we have would indicate that *B. dissectum* is at least partially, and probably entirely, sterile. Unfortunately the natural test which would prove or disprove this theory—germinating the spores—cannot be applied until someone learns how to make these baffling spores germinate. If the spores of *B. dissectum* germinate, we do not see why this species should not occur in groups, like *B. virginianum*, *B. obliquum*, *B. simplex*, and probably the other species.



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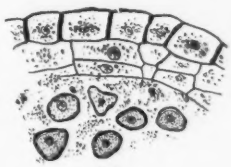

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FIGS. 10, 11.—Abortive sporangium of *B. dissectum*, with many-layered wall and mass of mucilage lining cavity from which sporogenous tissue has been resorbed; ×160: portion of sporangium of *B. dissectum*, showing spores of different sizes; triangular spore doubtless abortive; ×350.

In our opinion, the explanation of the occurrence and behavior of *B. dissectum* is that the species is a sterile mutant from *B. obliquum*. The principal facts supporting this theory are that *B. dissectum*, so far as I have observed in a five years' study, never occurs except in association with *B. obliquum*, and that there is no evidence that it reproduces itself.

It might be objected that mutants do not occur so frequently as *B. dissectum* would indicate, and it must be admitted that the total number of plants in our plots is not as large as one might wish in making ratios. The total number of plants in the twenty-four plots was 482 of *B. obliquum* and 19 of *B. dissectum*, a ratio

of 25:1. The ratio in the Oberlin group was 20:1; in the Sullivan group, about 48:1; and in the Cleveland group, 40:1.

However, in making any objections to the theory on the ground that *B. dissectum* occurs too frequently to be a mutant, it must be remembered that mutation in plants has been studied almost exclusively in angiosperms, which are heterosporous and which have comparatively low chromosome numbers. We are assuming that mutations occur in the mitotic mechanism, probably during the reduction divisions, so that the mutant, which one recognizes in the sporeling stage, is merely the result of a preceding phenomenon.

At first thought, someone might suggest that *B. dissectum* is a hybrid. What species could cross to give such characters as we find in *B. dissectum?* The mere question seems a sufficient answer, especially since *B. dissectum* is found when no other species except *B. obliquum* occurs in the vicinity. When we remember that the prothallia are of the tuberous, subterranean, saprophyte type, and not closely associated, the possibility of crossing seems very remote.

We believe the evidence is sufficient to raise a strong presumption that *B. dissectum* is a sterile mutant from *B. obliquum*.

UNIVERSITY OF CHICAGO

NEW OR NOTEWORTHY PORTO RICAN FUNGI

F. L. STEVENS

(WITH FOUR FIGURES)

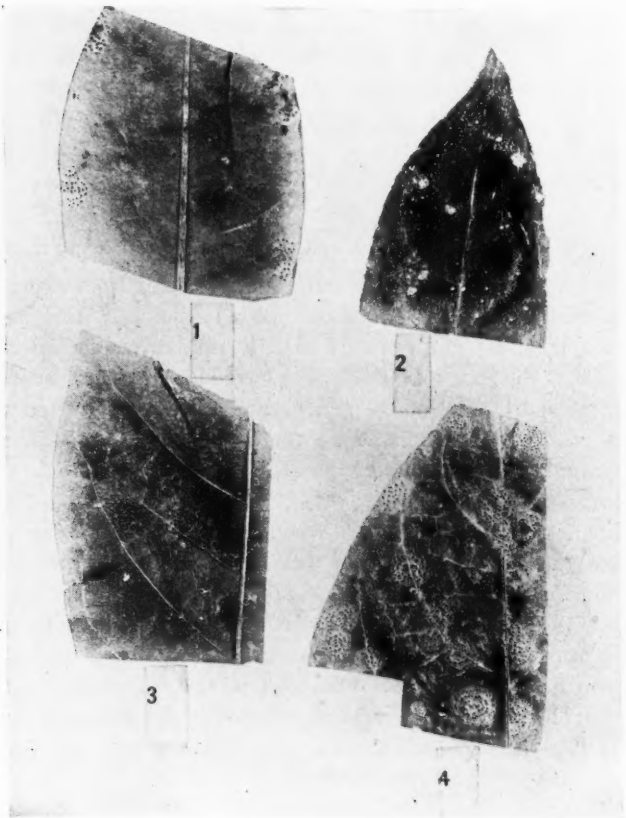
ANTHOSTOMELLA RHIZOMORPHAE (Ktz.) B. and V.—The spots caused by this fungus are pale to yellowish and are much swollen, so that they present a general aspect of insect galls. They are 0.5–1 cm. in diameter, circular, or when marginal more or less extended. Each spot contains several perithecia which are medially located in the leaf, that is, about equally distant from upper and lower epidermis. They are about 700 μ in diameter, thin-walled, the wall colorless, and have a coarse, hyaline mycelium extending throughout the spot, a black clypeus form in later stages occupying all of the space between the perithecium and the lower epidermis, which is 230–470 μ in diameter; the ostiole 40–50 μ in diameter. The paraphyses are numerous, threadlike, simple, septate, hyaline; asci oblong, stipitate, 150–175 or even 200 $\mu \times 50$ μ, thin-walled, 8-spored, inordinate. Spores oblong, 24–40 $\times$ 14–17 μ, brown when mature and 1-celled; the inner wall is uniform; the brown outer wall is pale yellow, wrinkled, and takes on very different appearances with different ages. Pycnidia are associated with the perithecia apparently on the same mycelium, oval, 125 μ across, 218 deep, with a thin clypeus; basidia short, simple; conidia oblong, pointed, obscurely 1-septate, pale straw colored, 3 $\times$ 10 μ.

On *Rhizophora Mangle*. Guanica, 2484; Penueles, 4559; Ponce, 8591, 9070; Cataño, 7607; San Jose Laguna, 9215.

The type is described on "coriaceous leaves" from Suriname, and may well have been on *Rhizophora*. The fungus is quite striking in appearance, but might be readily mistaken for an insect gall and thus overlooked by mycologists. The large spores with the several-layered coats, which give very striking appearances as they mature, are interesting structures.

Linospora trichostigmae, sp. nov.—Spots indefinite, 5–10 mm. in diameter, thickly studded with perithecia. Perithecia spherical, 150 to 200 to 250 μ in diameter, covered by a distinct clypeus and surrounded by a narrow (30–100 μ) pale zone. Clypeus

black, mostly epiphyllous, rarely hypophyllous. Ostiole irregular in shape. Asci cylindrical, 90–112×10–14 μ, thick-walled. Para-



FIGS. 1–4.—Fig. 1, *Anthostomella rhizomorphae*, showing black clypei in pale spots; fig. 2, *Linospora trichostigmae:* black perithecia in small, blanched, dead areas; fig. 3, *Trabutia portoricensis:* numerous clustered perithecia in poorly defined spots; fig. 4, *Trabutiella cordiae:* perithecia arranged in circles in dead spots.

physes few, fine, threadlike. Spores linear, filiform, several, septate, pale yellow. Conidia 1-celled, hyaline, pointed at each end, very variable in size, mostly 21–24×7 μ, but often 48 μ long,

and also often quite small, borne in cavities indistinguishable from the perithecia.

On *Trichostigma octandra*, Guayanilla, 5924.

The perithecia are conspicuous from above on account of the black clypeus, and from below because of the protuberance that they cause. At maturity the clypeus falls away, the contents of the perithecia drop out, and a hollow "poc-mark" cavity remains. The variability of the conidia is quite remarkable.

Trabutia portoricensis, sp. nov.—Spots approximately circular, densely set with perithecia, area of young spots not at all or but slightly discolored, tissue of old spots dead, tan colored. Perithecia conspicuous above, due to the shining black clypeus, from below by the protuberance which they cause. Perithecia opening epiphyllous, clypeus black, 80–95 μ in diameter. Ostiole central, 10–15 μ in diameter. Perithecium central in the mesophyll. Asci irregular, thin-walled, 8-spored, inordinate, $68\times17\ \mu$. Paraphyses many; spores filiform, oblong, obtuse, $24\times7\ \mu$, continuous, hyaline.

On *Cocolobis nivea*, Mayaguez, 3907a (type), 976.

Trabutiella, gen. nov.—Similar to *Trabutia*, but with the asci 16-spored. Similar to *Ditopella*, but distinguished from it by its clypeus. Type of genus the following.

Trabutiella cordiae, sp. nov.—Spots when young but slightly discolored; later the tissue dies and the spots are tan colored, or they may remain green longer than the adjacent healthy tissue. Spots definitely bordered, almost exactly circular, 5–10 mm. in diameter, with the perithecia in quite regular concentric rings. The black clypeus always epiphyllous, about 280 μ in diameter, or oblong and $240\times500\ \mu$. Ostiole 45–75 μ in diameter. Perithecia not visible from below, located in the mesophyll, 260–360 μ in diameter. Asci $85\times17\ \mu$, 16-spored, thin-walled, inordinate; spores oblong, pointed at each end, $20\times3.5\ \mu$, continuous, hyaline.

On *Cordia collococca*, Añasco, 276 (type); Mayaguez, 6295, 3907; Patillo Springs, 5730; Jayuda, 3977a; Hormigueros, 215.

Hyponectria phaseoli, sp. nov.—Spots circular, 5–10 mm. in diameter, amphigenous, few to numerous, often coalescing, pale yellowish, translucent, border indefinite. Perithecia abundant, immersed, translucent; when mature, with distinct protruding

ostiole which is surrounded by a dark border of clypeate structure, 200–230 μ in diameter. Ostiole 20 μ in diameter, dark ostiolar region 100 μ in diameter, opening mostly epiphyllous. Asci linear to clavate, 75 μ long, 8-spored. Spores 1-seriate, crowded irregularly at apex of ascus, irregularly spherical to oval, often angular by pressure, continuous, hyaline, 9–10×12 μ; paraphyses threadlike, equal in length.

On *Vigna vexillata*, Rosario 3602 (type); Añasco, 3509; Vega Baja, 374a; Mayaguez, 978, 1483, 813, 1098, 3149; on *Phaseolus adenanthus*, Mayaguez, 6732; San German, Añasco, 4903, 308; *Phaseolus* sp., on Luquillo, Forest, 5555.

Zythia phaseoli, f. nov.—The conidial stage of *Hyponectria phaseoli*. Pycnidiospores produced in what appear to be the young perithecia, oval to linear (mostly linear), hyaline, straight or slightly curved, obtuse at each end, continuous, 10–20×2–3 μ, often catenulate; conidiophores linear, long, branched.

On *Phaseolus*, 3149 (see also previous numbers).

This fungus is exceedingly abundant in Porto Rico, being found nearly as frequently as its host, and usually distributed thoroughly over the whole plant. It is of especially striking appearance, owing to its peculiar spot and the appearance, as though due to pellucid punctate dots, which is caused by the translucent perithecia.

The genus has but few representatives, perhaps less than a dozen, none of which agrees at all closely with the present species. On drying, the leaves show a peculiar tendency to dry out yellow in the healthy parts of the leaf, green in the sick parts. Only one other species seems to have been described with a conidial form, *H. buxi*, conidial form *Phoma mirbelii* (Fr.) Sacc.

UNIVERSITY OF ILLINOIS
URBANA, ILL.

CURRENT LITERATURE

BOOK REVIEWS

A practical plant biochemistry

MRS. ONSLOW[1] has just written an interesting descriptive text and laboratory manual on plant biochemistry. The author is already well known as an investigator of anthocyanins, and also as the author of "The anthocyanin pigments of plants," under the name of MURIEL WHELDALE.

The aim of the book is stated as follows: "This book is intended primarily for students of botany. Such students' knowledge of plant products is usually obtained, on the one hand from organic chemistry, and on the other hand from plant physiology. Between these two standpoints there is a gap, which, it is hoped, the following pages may help to fill. It is essentially a textbook for practical work, on an aspect of plant biochemistry which has received up to the present time very little consideration in teaching. A number of experiments have been devised and have been actually tested in practical classes. These experiments should enable a student to extract from the plant itself the chemical compounds of which it is constituted, and to learn something of their properties."

The book consists of the following chapters: Introduction (9 pp.); The colloidal state (7 pp.); Enzyme action (9 pp.); Carbon assimilation (15 pp.); Carbohydrates and their hydrolizing enzymes (38 pp.); Fats and lipases (8 pp.); Aromatic compounds and oxidizing enzymes (31 pp.); Proteins and proteases (24 pp.); Glucosides and glucoside-splitting enzymes (12 pp.); and Plant bases (12 pp.).

The reviewer believes the author has done plant science a great service in preparing the book. It should be welcomed by all workers in the field.—WM. CROCKER.

New Zealand plants

A country possessing a vegetation of more than usual luxuriance and variety is indeed to be congratulated when it is fortunate enough to have its forests and grasslands described by a botanist who combines a thorough scientific knowledge with the rare ability of presenting scientific facts in language at once accurate and intelligible to the citizen with no scientific training. COCKAYNE[2] seems to have accomplished this difficult task in a volume which

[1] ONSLOW, MURIEL WHELDALE, Practical plant biochemistry. 8vo. pp. 178. Cambridge: University Press. 1920.

[2] COCKAYNE, L., New Zealand plants and their story. 8vo. xv+248. *figs. 113.* 1919. 2d ed. Wellington: M. F. Marks, Government Printer.

is essentially a new book rather than a second edition of that formerly noted.[3]

Beginning with a sketch of the history of the botanical exploration of New Zealand, and noting the landmarks in her botanical literature, the author instructs the reader regarding the fundamental concepts of plant ecology in clear and simple terms, preparing him to follow appreciatively the description of New Zealand plants, not only considered as individuals, but as grouped in communities. Separate chapters are devoted to the vegetation of the sea coast, the inland waters, the mountains, and the outlying islands, as well as to the forests, the scrub, and the grasslands. The descriptions are so good that not only may they be understood by the New Zealand school boy (for it is an authorized textbook in the public schools), but they may also serve to furnish a graphic picture of a unique vegetation to the ecologists of other lands. For the latter the separation of New Zealand into botanical districts and the analysis of the flora into its different elements is particularly interesting. Moreover, the botanist is not at a loss to know what plants are intended by their common designations, for the scientific names always follow. In this, as well as in the use of many excellent illustrations, the volume may well be regarded as showing a standard of excellence seldom attained.—GEO. D. FULLER.

MINOR NOTICES

Cactaceae.—The second volume of the elaborate monograph of Cactaceae by BRITTON and ROSE[4] has just appeared. In fullness of description and wealth of illustration it leaves nothing to be desired. The colored plates are particularly noteworthy. The volume includes two of the eight subtribes of Cereae. In subtribe Cereaneae, 38 genera are recognized, including 16 new genera as follows: *Monvillea, Espostoa, Browningia, Stetsonia, Corryocactus Erdisia, Leocereus, Dendrocereus, Machaerocereus, Brachycereus, Jasminocereus, Binghamia, Arrojadoa, Facheiroa, Zehnterella,* and *Neoraimondia.* There are also described 40 new species distributed among the various genera. The subtribe Hylocereanae includes nine genera, *Wilmattea, Mediocactus,* and *Deamia* being new, and 48 species, 6 of which are new. The monograph is an impressive illustration of the extensiveness of the cactus flora and its need of taxonomic reconstruction.—J.M.C.

Flora of Jamaica.—The fourth volume of FAWCETT and RENDLE'S *Flora of Jamaica*[5] continues the Dicotyledons, which began in the third volume,

[3] BOT. GAZ. **52**: 159. 1911.

[4] BRITTON, N. L., and ROSE, J. N., The Cactaceae. Vol. II. Publ. Carnegie Inst. no. 248. pp. vii+239. *pls.* 40. *figs.* 305. 1920.

[5] FAWCETT, W., and RENDLE, A. B., Flora of Jamaica, containing descriptions of the flowering plants known from the island. Vol. IV. Dicotyledons (Leguminosae to Callitrichaceae). 8vo. xv+369. *figs.* 114. Published by the British Museum. 1920.

published in 1914.[6] The volume includes 13 families, much the largest ones being Leguminosae and Euphorbiaceae, with 50 and 30 native genera respectively, the remaining 11 families being represented by 34 genera. The contrast with north temperate floras is striking in the relative display of the various genera. For example, in the range of GRAY'S *Manual*, 11 native genera and 40 species of Euphorbiaceae are recorded, while in Jamaica this family is represented by 34 native genera and 111 species.—J.M.C.

Honey plants.—PELLETT[7] has listed alphabetically under their common names all plants known to contribute to the honey supply of the country. Simple descriptions and many rather good illustrations from photographs will enable the bee keeper to recognize the species in his particular locality, while scientific names insure accuracy. Some attention is also given to plants affording an abundant pollen supply. The volume should prove useful to the bee keeper, and interesting to the botanist or ecologist.—GEO. D. FULLER.

NOTES FOR STUDENTS

Taxonomic notes.—DRUMMOND and HUTCHINSON[8] have disintegrated the genus *Isopyrum* as ordinarily presented, separating from it 6 genera, *Asteropyrum* and *Paraquilegia* being described as new. The other separated genera are *Leptopyrum* Reichb., *Enemion* Raf., *Semiaquilegia* Makino, and *Souliea* Franch. There are 12 species retained in *Isopyrum*, one of which is new. This involves much shifting of nomenclature. For example, our common *Isopyrum biternatum* becomes *Enemion biternatum* Raf.

MOORE,[9] in continuation of his studies of the African flora, has described new genera in Erythroxylaceae (*Umbellulanthus*) and Icacinaceae (*Monocephalium*). In addition, 11 new species are described in these families and in Olacaceae.

WILDEMAN[10] has presented the African species of *Rinorea* (Violaceae), with full analytical keys and distribution, recognizing 106 species, 19 of which are described as new.

MOORE[11] has described the following new genera: *Homaliopsis* (Flacourtiaceae) and *Vaughania* (Leguminosae) from Madagascar, and *Hulemacanthus* (Acanthaceae) from Papua.

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[6] BOT. GAZ. **59**:334. 1915.

[7] PELLETT, F. C., American honey plants. 8vo. pp. 287. *figs.* 152. 1920. Hamilton, Ill. American Bee Journal.

[8] DRUMMOND, J. R., and HUTCHINSON, J., A revision of *Isopyrum* (Ranunculaceae) and its nearer allies. Kew Bull. 1920: no. 5. pp. 145–169.

[9] MOORE, SPENCER LE M., *Alabastra diversa*. XXXIII. 3. Miscellanea Africana. Jour. Botany **58**:219–226. 1920.

[10] WILDEMAN, E. DE, Notes sur le genre *Rinorea* Aubl. Bull. Jard. Bot. Bruxelles. **6**:131–194. 1920.

[11] MOORE, SPENCER LE M., *Alabastra diversa*. XXXIII. 1. Plantarum Mascarensium pugillus. 2. Acanthaceae Papuanae. Jour. Botany **58**:187–195. 1920.

ZIJP[12] has described a new genus (*Pseudodatura*) based on *Datura arborea* L. It had also been referred to *Brugmansia* by STEUDEL.

STAPF[13] has published a new genus (*Thellungia*) of Gramineae growing in Switzerland. It is related to *Sporobolus*, and the type is "an alien grown from wool refuse" about a mill. It is possibly of Australian origin, since numerous Australian grasses occur in the "rich alien flora" around the mill.

DUNN[14] has described a new genus (*Smithiella*) of Urticaceae from Eastern Himalaya. The genus is dedicated to Miss MATILDA SMITH, whose drawings and paintings for many years have been published in the *Botanical Magazine*, *Icones Plantarum*, and *Kew Bulletin*.

BROWN[15] has presented the results of his study of *Mesembryanthemum*, describing new species and also wishing "to demonstrate to future monographers the necessity for a thorough revision of the nomenclature of this interesting genus, as in the later monographs of it I have found that there are many errors in identification." Descriptions of 112 species are given, 62 of which are new. Two principal divisions of the genus are recognized, namely stemless species and those with stems, and under these divisions the species are distributed among 31 sections.

The Bolus Herbarium,[16] in continuation of its studies of African plants, has published 22 new species in various genera, an extensive list of flowering plants collected in Southwest Africa by the Percy Sladen Memorial Expedition (1915–1916), 6 new species of *Adenandra*, and 28 new species of *Agathosma*, both genera of Rutaceae.

OSTENFELD,[17] in connection with his studies of the West Australian flora, has published a revision of the following genera: *Triglochin* (7 spp.), *Crassula* (6 spp.), and *Frankenia* (15 spp.). New species are published in *Crassula* (1) and *Frankenia* (3).

VAN ALDERWERELT VAN ROSENBURGH,[18] in continuation of his studies of Malayan ferns, has discussed numerous species already credited to the flora, and described 50 new species. There are included also descriptions of 9 new species of *Selaginella* and a new *Lycopodium*.

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[12] ZIJP, C. VAN, *Pseudodatura*, nov. gen. Over. Natuur Tyds. Ned.-Indiè. 1920. 24–28.

[13] STAPF, O., *Thellungia*, a new genus of Gramineae. Kew Bull. 1920:96–99. *figs. 11.*

[14] Decades Kewenses. Kew Bull. 1920:210–212. *figs. 9.*

[15] BROWN, N. E., New and old species of *Mesembryanthemum*, with critical notes. Jour. Linn. Soc. **45**:53–140. *pls. 5–10.* 1920.

[16] Annals Bolus Herb. **3**:1–66. *pls. 2.* 1920.

[17] OSTENFELD, C. H., A revision of the West Australian species of *Triglochin*, *Crassula* (*Tillaea*), and *Frankenia*. Dansk Botanisk Arkiv **2**:30–55. *pl. 4. figs. 19.* 1918.

[18] VAN ALDERWERELT VAN ROSENBURGH, C. R. W. K., New or interesting Malayan ferns. Bull. Jard. Bot. Buitenzorg **2**:129–186. 1920.

DIXON[19] has published a report on the mosses of the Dümmer-Maclennan Expedition to Mount Elgon in 1918, and also on a small collection from the Aberdale Mountains. In the larger collection 46 species are reported, representing 32 genera. Ten new species, in as many genera, are reported for the smaller collection, and a new genus is established (*Kleioweisiopsis*) in Pottiaceae.

LANGE, [20] in his third part of the Agarics of Denmark, presents *Pluteus* (15 spp.), *Collybia* (28 spp.), and *Inocybe*. (47 spp.). Only 4 new species are described (in *Inocybe*), but there are many transfers, based upon new conceptions of species and genera.

SETCHELL and GARDNER[21] have described 16 new species of marine algae, distributed among 9 genera, one of which (*Internoretia*) is new. It is an endophyte, "growing within the membranes of *Porphyra Naiadum*." The same authors,[22] in the second part of their monograph of the marine algae of the Pacific Coast, have published the Chlorophyceae. The analytical keys, full descriptions, excellent illustrations, and complete bibliography, present the group in a most satisfactory way. The group is represented by 6 orders, 13 families, 34 genera, and 136 species. The largest genera are *Cladophora* (17 spp.), *Enteromorpha* (16 spp.), and *Ulva* (13 spp.).

BØRGESEN[23] has issued the third and fourth parts of his "Marine algae of the Danish West Indies," which continue the presentation of the Rhodophyceae. The two parts include 75 species, two of which are new, distributed among 29 genera. *Mesothamnion* is established as a new genus of the Ceramiaceae.—J.M.C.

Ovules and seeds of Thymeleaceae.—GUÉRIN[24] has investigated the anatomical structure of the ovule and seed of 27 genera of the Thymeleaceae. In the ovule the entrance to the micropyle is obstructed more or less by elongated cells which arise from the base of the stylar canal and become many-celled hairs. In some genera these cells are massed together and constitute a kind of obturator, which does not seem to hinder the penetration of the pollen

[19] DIXON, H. N., Reports upon two collections of mosses from British East Africa. Smithson. Miscell. Coll. **72**: no. 3. pp. 20. *pls. 2*. 1920.

[20] LANGE, JAKOB E., Studies in the Agarics of Denmark. III. Dansk Botanisk Arkiv **2**:1–47. *pls. 1–3*. 1917.

[21] SETCHELL, W. A., and GARDNER, N. L., Phycological contributions. 1. Univ. Calif. Publ. Bot. **7**:279–324. *pls. 21–31*. 1920.

[22] ———, The marine algae of the Pacific Coast of North America. Part II. Chlorophyceae. Univ. Calif. Publ. Bot. **8**:139–374. *pls. 9–33*. 1920.

[23] BØRGESEN, F., The marine algae of the Danish West Indies. III and IV. Rhodophyceae (3 and 4). Dansk Botanisk Arkiv **3**:145–240, 241–304. *figs. 82* and *77*. 1917 and 1918.

[24] GUÉRIN, PAUL, Recherches sur la structure anatomique de l'ovule et de la graine des Thyméléacées. Ann. Jard. Bot. Buitenzorg II. **14**:1–35. 1915.

tube; in fact, in some genera these hairs seem to serve rather as a guide to the pollen tube. The fusion of the polar nuclei is tardy. The antipodals are always more than 3 in number, and in some genera very many more. The most striking feature of the ovule is the "hypostase" of VAN TIEGHEM, which is a clearly differentiated group of cells beneath the embryo sac, whose thin walls give the lignin reaction to stains. It occurs sometimes immediately beneath the embryo sac and sometimes deep in the chalaza. Its function is doubtful. The author raises the question whether it is not a distinct disadvantage in shutting off water conduction to the embryo sac.

In connection with seed development the author followed the changes in the tissues of the 2 integuments, finding that the inner integument contributes chiefly to the testa, but its persistent innermost layer separates from the testa and becomes a thin pellicle completely covering the embryo. In some of the genera in connection with seed formation, tracheae are developed in the periphery of the nucellus, connecting with the strands of the raphe and traversing the whole length of the nucellus. The author suggests that this is comparable to the tracheal nucellar mantle which characterizes the seeds of some of the Cycadofilicales. This feature has not been discovered before in the seeds of living plants.—J. M. C.

Tree growth.—MACDOUGAL[25] has issued a preliminary report describing briefly an instrument for recording the variations in diameter of tree trunks. Records extending over several months have now been made of individual trees of *Fraxinus arizonica*, *Pinus chihuahuana*, *P. radiata*, *Quercus agrifolia*, *Fagus grandifolia*, and *Platanus occidentalis*.

SHREVE[26] has added to these data a preliminary report of determination made on some stumps of *Pinus radiata*. The maximum increase in diameter for 10 years was 14 inches, while growth in height of 10 ft. for trees 12–15 inches in diameter has been known.—GEO. D. FULLER.

A new atmometer.—BATES[27] has devised a new atmometer which is said to have very nearly the same relation to wind and radiant energy as do the leaves of trees. A flat metallic chamber is constructed with a layer of moist linen between the upper and lower plates. The upper plate not only protects from rain, but also, possessing a blackened surface, absorbs radiant energy freely, while the lower plate is perforated to resemble the stomatal surface of leaves. Experiments have shown that the evaporation from this instrument follows the transpiration from small coniferous trees very closely.—GEO. D. FULLER.

[25] MACDOUGAL, D. T., The dendrograph. Carn. Inst. Wash. Year Book for 1919. **18**:72–78. 1920.

[26] SHREVE, FORREST, Stem analysis and elongation in shoots of Monterey pine. Carn. Inst. Wash. Year Book for 1919. **18**:88–89. 1920.

[27] BATES, C. G., A new evaporimeter for use in forest studies. Mo. Weather Rev. **47**:283–294. *figs. 3*. 1919.